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Asymmetry of function an investigation of cognitive processing strategies in the left and the right cerebral hemispheres.

Valorie L. Selland
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ASYMMETRY OF FUNCTION: AN INVESTIGATION OF COGNITIVE PROCESSING STRATEGIES IN THE LEFT AND RIGHT CEREBRAL HEMISPHERES

by

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ABSTRACT

The present experiment comprised an investigation of cerebral asymmetry (i.e., differences in the way the two hemispheres function). Two recent theories concentrated on information-processing methods to study and explain the differences. One model (Shatz, 1979) suggested that the left cerebral hemisphere processes items in a manner which would be consistent with a serial memory scan and the right cerebral hemisphere processes items in a manner which would be consistent with a parallel memory scan. Another model (Goldberg & Costa, 1981) proposed that asymmetry of function is a consequence of neuroanatomical differences between the cerebral hemispheres. These researchers suggest that the right cerebral hemisphere is superior in processing information when the subject is presented with novel stimuli and the left hemisphere is superior in processing information for which there is a pre-existing code or strategy. This experiment was designed to investigate the cognitive information-processing strategy used within each cerebral hemisphere, for both familiar and novel stimuli, and to determine if there is any change in processing over time as novel stimuli become familiar.

Fourteen right-handed male subjects, ranging in age from 19 to 41 years with a mean age of 24.14 years, received

tachistoscopic presentation of stimuli, defined as "familiar" (i.e., digits from 1 to 9) or "novel" (i.e., a set of 9 angles varying with respect to angle size and degree of rotation), on three consecutive days. A memory set, consisting of 2, 3, or 4 digits (or angles) was presented to each subject. Each of the 9 digits/angles (probes) was randomly presented either to the right or left visual field (laterality), with each subject instructed to report that the probe had been (positive probe) or had not been (negative probe) one of the 2, 3, or 4 digits/angles seen at the beginning.

The hypotheses of the present experiment were only partially supported. A right visual field (left hemisphere) advantage was observed with familiar stimuli (i.e., digits). However, no visual field advantage was observed for novel stimuli (i.e., angles) and consequently the hypothesis of a right-to-left shift in hemispheral superiority for processing novel stimuli could not be evaluated. The hypothesis of differential memory scanning strategies between the left and right cerebral hemispheres could not be evaluated since the reaction time curves observed did not meet the criteria used to differentiate serial and parallel scanning.

The relationship of the present findings to previous research was discussed. Possible reasons for non-support of some predictions were presented. Finally, suggestions for further research were proposed.

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TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Throughout the history of neuropsychology, an emphasis has been placed on determining the nature of the differences in function between the two cerebral hemispheres. Terms used to describe this asymmetry of function have ranged from "dominant/non-dominant" to "linguistic/non-linguistic" and "analytic/gestalt." Early approaches to the issue of cerebral asymmetry could be described as "localizationism" whereby particular functions were associated with one or the other cerebral hemisphere. More recent approaches are characterized by the use of cognitive information-processing methodology, in which there is an emphasis on determining the underlying cognitive strategies within each cerebral hemisphere (Moscovitch, 1979; Schmuller, 1979).

Two recent articles have appeared in which a cognitive information-processing approach has been used to describe cerebral asymmetry. Shatz (1979), on the basis of results obtained in three experiments, suggested that the left cerebral hemisphere processes items in a manner which would be consistent with a serial memory scan and the right cerebral hemisphere processes items in a manner which would be consistent with a parallel memory scan. Goldberg and

Costa (1981) proposed that asymmetry of function is a consequence of neuroanatomical differences between the cerebral hemispheres. They suggested that the right cerebral hemisphere is superior in processing information when the subject is presented with novel stimuli and the left hemisphere is superior in processing information for which there is a pre-existing code or strategy. This experiment was designed to investigate the cognitive information-processing strategy used within each cerebral hemisphere, for both familiar and novel stimuli, and to determine if there is any change in processing over time as novel stimuli become familiar stimuli.

In the literature review which follows, three areas of research will be examined. First, research concerning the information-processing approach and its application within the area of neuropsychology will be presented. Next, a discussion of serial and parallel processing and research relevant to Shatz's (1979) model of cerebral asymmetry will be surveyed. Finally, the Goldberg and Costa (1981) model of cerebral asymmetry will be presented, followed by a statement of the purpose and hypotheses of the present experiment.

Information Processing Approaches in Neuropsychology

Techniques borrowed from experimental psychology have been utilized to investigate cerebral asymmetry. In this

section, the methodology and general findings of these techniques will be reviewed as they are applied to visual information-processing studies.

With respect to the visual system, anatomical arrangements are such that information presented to one or the other visual field follows a specific pathway to one or the other cerebral hemisphere. That is, information presented in the left visual field projects to the right cerebral hemisphere, and information presented in the right visual field projects to the left cerebral hemisphere. Superiority of one or the other cerebral hemisphere is usually determined on the basis of a reaction time measure. That is, the basic procedure in these experiments requires a subject to focus his or her eyes on a designated point in the center of a visual display and information is presented to one or the other visual half field. The time (in msec.) to a response is measured, and the cerebral hemisphere for which a shorter reaction time is found is considered to be superior at processing that type of information. Superiority can also be determined using a measure of accuracy of recognition (Dimond & Beaumont, 1974).

This procedure has been used to investigate cerebral asymmetry with both normal subjects and patients with surgical disconnection of the cerebral hemispheres. In the early research in this area, some consistent results were reported, using both subject populations. One major

issue focused on differences in the processing of verbal versus nonverbal material. The left cerebral hemisphere was often found to be superior to the right cerebral hemisphere for identification of letters, digits, words, and other stimuli which could be verbally encoded. The right cerebral hemisphere was often found to be superior on recognition tasks for nonverbal stimuli, such as tasks requiring the identification of faces, dot localization, and recognition of geometric shapes (Dimond & Beaumont, 1974; Pirozzolo, 1977).

Although these findings were generally accepted in the earlier phase of research on cerebral asymmetry, many inconsistent results were also evident. For example, White (1972) summarized the results from forty-one experiments in which stimuli were unilaterally presented to the right or left visual field. In fifteen out of twenty-five experiments which utilized nonverbal stimuli, no hemifield differences were observed for recognition of these stimuli. In the sixteen experiments which utilized verbal stimuli there was somewhat more consistency in the results, favouring a right visual field (left hemisphere) advantage. However, discrepant results have also been reported in research utilizing verbal material. By investigating the discrepancies reported in the literature, researchers became more aware of the effect which methodological variables have on determining cerebral asymmetry. One such study will be

presented in order to demonstrate the importance of methodological variables on visual hemifield superiority.

Mishkin and Forgays (1952) investigated reaction time for recognition of words, using subjects who were bilingual in the English and Yiddish language. In one phase of the experiment, English words were unilaterally presented to the left or right visual field. In a second phase of the experiment, Yiddish words were presented for recognition. Mishkin and Forgays reported that a lower reaction time was found for English words presented in the right visual field than in the left; the opposite results were obtained for Yiddish words. Mishkin and Forgays proposed that this difference was related to the training procedures used in each language for reading. That is, the English language is read from left to right and the Yiddish language from right to left, and these training procedures were assumed to result in a more effective "neural organization" in the left cerebral hemisphere for the English language and in the right cerebral hemisphere for the Yiddish language.

Heron (1957) modified the Mishkin and Forgays (1952) study, using a bilateral tachistoscopic presentation procedure rather than unilateral presentation for English letters and words. The reaction time measures indicated a left visual field (right hemisphere) advantage for recognition of the stimuli. These results contradicted the Mishkin and Forgays hypothesis, which postulated that a

more efficient neural organization was established in the left cerebral hemisphere for English words on the basis of acquired reading habits (White, 1969; Pirozzolo, 1977).

Discrepant results in the literature have also been provided by experiments in which superiority of the left visual field (right hemisphere) has been demonstrated for verbal tasks such as word-matching, letter-matching, recognition of cursive handwriting, and recognition of unfamiliar typefaces (Pirozzolo, 1977). Inconsistent results such as these led researchers away from a characterization of stimuli or hemispheres as being primarily verbal or nonverbal in nature, and toward the investigation of methodological issues involved in visual information-processing studies (Pirozzolo, 1977). Reviews of the research in this area have been reported by White (1969, 1972).

White (1969) reviewed the literature on laterality differences obtained in experiments in which visual stimuli were tachistoscopically presented to subjects. He reported that "whether a left or a right visual hemifield superiority in recall accuracy is found is dependent on (a) the type of stimulus presentation, unilateral or bilateral; (b) the amount, nature, and spacing of the stimulus-information elements; (c) the intensity at which the information is shown; (d) the order in which the information is reported; (e) the viewing condition employed, and the ocular dominance

of the subjects; and (f) the handedness and lateralization of the subjects" (p. 402). Other methodological issues related to asymmetry of function and visual information processing will now be reviewed. These issues include: the number of items in a stimulus presentation (Moscovitch, 1972); the effects of cuing (Cohen, 1975); the type of stimulus and fixation stimuli (Hines, 1978); and task requirements (Cohen, 1972; Niederbuhl & Springer, 1979; Martin, 1979).

Moscovitch (1972) investigated the effects of memory set size on cerebral dominance. The memory set, which was composed of a set of one or six letters, was auditorily presented to subjects to both ears at the same time. Following presentation of the memory set, a test letter was visually presented for recognition to either the left or right visual field. Moscovitch reported that hemispheral superiority, as determined by a reaction time measure, was dependent upon the size of the memory set. That is, when the memory set consisted of one letter, reaction time favoured a left visual field (right hemisphere) presentation. When the set size was increased to six letters, a right visual field (left hemisphere) superiority was demonstrated. Moscovitch also demonstrated that reaction time measures are not biased in favour of the visual field projecting to the hemisphere that emits the motor response.

Cohen (1975) investigated the effects of cuing on visual recognition tasks. In one experiment, single letters were presented in the left or right visual field. The subject's task was to name the letter as quickly as possible. Half of the trials were non-cued trials in which the experimenter said "no information" prior to a stimulus presentation. Half of the trials were cued with two alternative letters verbally supplied prior to the stimulus presentation, one of which corresponded to the stimulus. Cohen reported that no hemispheric asymmetry was observed when single letters were presented to subjects using the uncued recognition procedure. However, with the cued recognition procedure a right visual field (left hemisphere) advantage was observed.

Cohen (1975) replicated this experiment using single words as visual recognition stimuli. Cohen reported that recognition of words was faster in the right visual field (left hemisphere) on uncued trials. This right visual field advantage for words was also obtained in cued trials, in which the subject was supplied with the class or category of the stimulus word which would appear.

Cohen (1975) reported one additional experiment which was designed to investigate the effects of cued versus non-cued presentation of visual stimuli on cerebral asymmetry. In this experiment, a mixed series of words, digits, and dots was presented. Cohen reported that no asymmetry was

observed for any stimulus on uncued trials. A left hemisphere advantage for words was demonstrated when a cue indicated the type of stimulus which would follow. No significant shift in hemisphere advantage was obtained for digit or dot stimuli in the cued condition. On the basis of results obtained in all three experiments, Cohen concluded that, in some conditions, the hemispheric asymmetry observed for a particular task may shift when cuing establishes an attentional set.

In visual information-processing studies, subjects are often required to respond to a central fixation stimulus prior to presentation of the test stimulus in order to ensure that their eyes were focused at the center of the screen. Hines (1978) designed an experiment to investigate whether or not the type of fixation stimulus (i.e., verbal or nonverbal) alters visual half field asymmetry. In the verbal center control stimulus condition, subjects had to verbally report a single digit. The non-verbal center control stimulus consisted of a line of a particular orientation which a subject was required to recognize from a card listing several alternative lines. The stimuli used for the recognition task in this experiment consisted of words, faces, and random shape stimuli. Hines reported that visual half field asymmetry was determined by the type of stimulus presented in the visual half field rather than by the type of fixation stimulus. That is, the word stimuli

were recognized more often when presented in the right visual half field and the type of center control stimulus had no effect on recognition. The face stimuli were recognized more often when presented in the left visual half field, and this superiority was somewhat greater on trials in which a nonverbal center control stimulus was presented. The random shape stimuli showed no reliable visual half field asymmetry. Hines concluded that, in contrast to previous reports, visual half field asymmetry is not consistently altered by the type of center fixation stimulus.

Three experiments will be presented in which the effects of task requirements on cerebral laterality observed in visual recognition tasks was investigated. Cohen (1972) utilized a letter identification task in which letter pairs could be classified as "same" or "different" on the basis of nominal or physical analysis. Stimuli were unilaterally presented to the left or right cerebral hemisphere. Cohen reported that name matches were faster when stimuli were presented to the left hemisphere and physical matches were faster when stimuli were presented to the right hemisphere. In other words, hemispheric differences in performance on this task were not related to the type of stimulus presented, but were related to the type of processing required.

Niederbuhl and Springer (1979) investigated the effects of type of response strategy on recognition of a target set which consisted of four letters. Subjects in a "name"

condition were instructed to memorize the names of the target letters and were required to rehearse them before each trial. Subjects in a "shape" condition were informed that all target letters were composed of straight lines while all distractor letters contained curves. This group of subjects was instructed to look only for straight lines to identify targets, and not at any specific letters. It was reported that when task instructions stressed naming, the left hemisphere was superior to the right. When the task instructions required subjects to respond on the basis of shape, superior processing was demonstrated for stimuli presented to the right hemisphere.

Martin (1979) investigated hemispheric specialization for "holistic" and "analytic" processing. The stimuli consisted of a presentation of one of three large letters (i.e., the letter "H", "S", or "O"). These large letters, referred to as the "global" shape of the stimulus, were in turn composed of small letters (i.e., the letters "H", "S", or "O"). These small letters were referred to as "local" elements (Figure 1). Subjects were instructed to recall either the global or the local shape of the stimuli which assumed holistic and analytic processing, respectively. When subjects were required to respond on the basis of the local elements, processing was significantly faster for stimuli presented in the right visual field (left hemisphere). When subjects were required to make a global

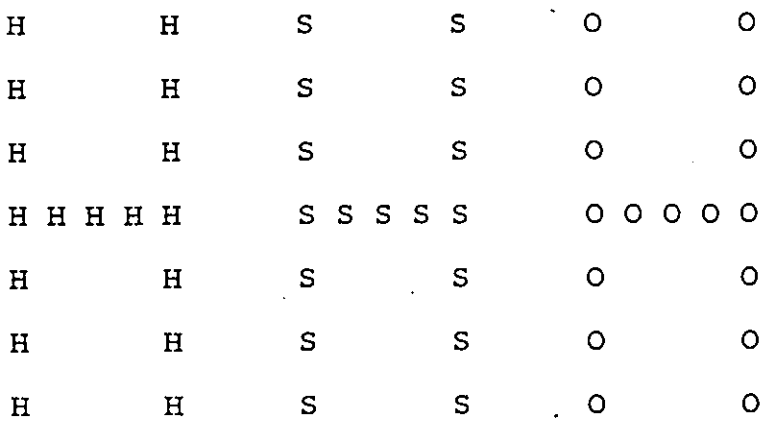

Figure 1. Example of stimulus patterns used in Martin's (1979) experiment.

judgment, processing was significantly faster for stimuli presented in the left visual field (right hemisphere).

In summary, the research reviewed in this section accentuates the importance of methodological issues in visual information-processing experiments. Variables related to the visual stimuli, such as the number of items and the type of stimuli presented, have been shown to influence the laterality effects observed. In addition, task requirements, encoding strategy that the subject is to utilize, and instructions which provide a cue prior to presentation of the stimulus also influence the results. These methodological variables must be considered when designing studies in this area and when evaluating the results obtained in these experiments.

In the next section, research concerning serial and parallel processing strategies will be reviewed. First, the item recognition paradigm will be described, with a definition of the concepts of serial and parallel processing. The research pertaining to cerebral asymmetry with respect to serial and parallel processing will be presented, with an emphasis on Shatz's (1979) research.

Serial and Parallel Processing

The process of internal memory scanning was first proposed by Sternberg in 1966. The differentiation between

serial and parallel processing is based on results obtained in the "item recognition" paradigm. In this paradigm, "stimulus ensemble" refers to all items that are presented for the subject to memorize. These items comprise the "memory set." The remaining items comprise the "negative set." When a test stimulus is presented, the subject's task is to decide whether the item is a member of the positive set (the memory set) or of the negative set. The subject must press one of two buttons to make either a positive or a negative response.

Over several studies in which the size of the positive set was varied while the number of positive and negative responses required were kept constant, Sternberg (1969, 1975) integrated four main findings by using the concept of serial processing. He found that reaction time increased approximately linearly with an increase in set size. The rate of this increase was the same for both positive and negative responses. The rate of increase was about 38 msec. for each item in the positive set, and the zero intercept was about 400 msec. Similar results were obtained when the positive set remained the same over a series of trials, or was varied from trial to trial. Sternberg (1975) explained these findings by postulating "a search through the positive set in which the test item is compared serially to each of the memorized items, and each comparison results in either a match or a mismatch" (p.4).

In serial scanning, the search is believed to be an exhaustive one through the positive set where each test item is compared to each of the memorized items in serial order. Serial scanning then involves a series of comparisons. In parallel scanning, many separate comparisons are believed to occur at one time. That is, the test stimulus is compared in parallel (i.e., simultaneously) to all members of the positive set (Sternberg, 1975). Parallel scanning is believed to occur when there is no increase in reaction time as a function of change in the size of the memory set.

In summary, the processes of serial and parallel scanning are defined by the presence or absence of changes in reaction time that occur as a function of set size. If there is a linear increase in reaction time as the size of the positive set increases, serial scanning is assumed to have occurred. If there is no change in reaction time as a function of an increase in the memory set, then a parallel memory search is assumed.

Some researchers have criticized Sternberg's method of differentiating between serial and parallel processing. Townsend (1972, 1976) investigated the assumptions of serial and parallel processing by means of mathematical analysis. In a series of mathematical proofs, Townsend demonstrated that, given certain probability distributions, it is impossible to determine whether a linear increase in reaction

time is indicative of serial processing or of a limited capacity parallel system. However, he stated that a flat reaction time function offers strong support for an unlimited capacity parallel system. Townsend concluded that it is difficult to differentiate serial and parallel processing strategies using mathematical analysis. Taylor (1976) performed a similar analysis of serial and parallel processing curves and arrived at the same conclusion as Townsend.

The criticisms formulated by Townsend (1972, 1976) and Taylor (1976) against Sternberg's techniques for differentiating serial and parallel processing are theoretically correct. It may not be possible to discern serial and parallel processing on the basis of analysis of a single reaction time curve. However, it must be remembered that with research in this area the focus is not on the analysis of a single reaction time curve. Rather, the emphasis is placed on the comparison of reaction time curves obtained with different manipulations of the independent variable, or of the comparison of reaction time curves obtained for right and left hemisphere presentations. It can be inferred that differences between two reaction time curves represent differential processing strategies. Therefore, the terms "serial" and "parallel" can provide a meaningful way to describe observed differences in processing strategy, and Sternberg's techniques for distinguishing between these processes are widely accepted and used (Shatz, 1979). The

next section of this discussion will focus on research pertaining to serial and parallel processing and cerebral laterality.

Processing Strategy and Cerebral Laterality

Investigations have been done to determine the interaction between type of processing (i.e., serial or parallel) and cerebral laterality. These investigations have been reported by Klatzky and Atkinson (1971), Cohen (1973), White and White (1975), and Shatz (1979). This research will now be reviewed.

Klatzky and Atkinson (1971) presented subjects with memory set stimuli consisting of from two to five letters. Two types of test stimuli were used over different sessions. In some sessions, letters were presented laterally to subjects as test stimuli; in other sessions pictures were used as test stimuli. The picture stimuli were designed to represent a common noun whose first letter corresponded to a member of the letter set. The reaction time functions obtained for both the letter and picture stimuli showed a linear increase, for both positive and negative responses, as a function of an increase in memory set size. Klatzky and Atkinson concluded that their results were consistent with the serial exhaustive scanning model.

Cohen (1973) reported the results from three experiments in which hemisphere differences in serial and parallel

processing were investigated. In the first experiment, a set consisting of two, three, or four letters was presented in either the left or right visual field. The subjects' task was to decide if all the letters were the same or if one differed from the others. Cohen found a linear increase in reaction time as a function of an increase in the size of the letter set when the stimuli were projected to the right visual field (left hemisphere). No increase in reaction time was found when the stimuli were presented to the left visual field (right hemisphere). Cohen concluded that the left hemisphere processed the items in a serial manner and the right hemisphere processed the items in a parallel manner.

Cohen designed a second experiment to determine if similar results would be obtained when nonverbal material was used. The stimuli consisted of complex shapes which could not readily be encoded using a verbal strategy. Cohen found the left hemisphere to be superior for recognition of stimuli requiring a "same" response. The only significant linear increase in reaction time for "same" responses was found between the set size of two and three shapes for stimuli presented to the left hemisphere. There were no differences between the cerebral hemispheres for items which required a "different" response. There was an increase in reaction time with an increase in the number of items for both hemispheres, however, this increase was very small and

could not be determined to reflect either serial or parallel processing. Cohen concluded in the second experiment that the right hemisphere exhibited parallel processing, although there was a slight trend toward faster reaction time with more shapes present. The left hemisphere could not be characterized as showing either serial or parallel processing.

A third experiment was reported by Cohen (1973) in an attempt to clarify the issue of cerebral laterality and processing strategy. In this experiment, memory set size was increased to five items and letter stimuli were presented on half of the trials, with shape stimuli presented on the remaining trials. Cohen reported that letters presented to the left hemisphere were processed in a serial manner, and, when presented to the right hemisphere, the results did not reflect serial processing. Nonverbal stimuli appeared to be processed in a parallel manner by both hemispheres. Cohen concluded, on the basis of the results obtained over all three experiments, that hemispheric differences in processing strategy may be limited to tasks such as those requiring matching of alphanumeric stimuli or words which can be processed with either a verbal or visual-spatial strategy.

White and White (1975) attempted to extend Cohen's (1973) findings using geometric shapes and letter sets which were either physically identical or nominally identical. Two, three, or four items were presented to the

left or right visual field. With the geometric shape stimuli, subjects were required to indicate whether the items were the same or different. With the letter stimuli, subjects were required to indicate whether the stimuli were the same or different in both a physical and a nominal match condition. Overall, the results indicated that the reaction times for "same" responses were faster than those for "different" responses. For the letter stimuli, a faster reaction time was found in the physical identity condition than in the nominal identity condition. With the geometric stimuli, reaction time was significantly faster for right hemisphere presentation than for the left hemisphere. However, no significant interactions were obtained between set size and hemisphere of presentation. White and White suggested that response and pattern configuration effects may have contributed to the lack of hemisphere effect.

Before describing Shatz's (1979) research pertaining to serial and parallel processing and cerebral laterality, it is important to mention that methodological issues appear to have a significant effect on the type of processing strategy which will be observed. As discussed above, the results obtained prior to Shatz's (1979) study were often contradictory and confusing. The diversity in the results obtained may be related to differences between experiments with respect to the type of stimuli used, the duration of the stimulus presentation, or to other methodological

variables.

Research in this area since Shatz's (1979) experiment has also been somewhat contradictory. For example, Hellige (1980) sometimes observed serial reaction time curves with information presented to both the left and right visual fields. At other times, he obtained reaction time curves in both visual fields which were indicative of parallel processing. However, Hellige was also investigating the effects of quality of the stimuli used (i.e., whether or not the stimuli were perceptually degraded) on reaction time, and this variable may have affected the reaction time curves obtained. Madden and Nebes (1980) also demonstrated a linear increase in reaction time with an increase in set size for both visual field presentations. It is very difficult to compare these findings with Shatz's (1979) research because of many methodological differences between the experiments.

Given the significantly larger number of trials on which Shatz's reaction time curves are based, and the stability of Shatz's results over three different experiments using two sensory modalities, it is argued that Shatz's data are more representative of the processing strategies underlying each cerebral hemisphere. That is, it is proposed that the serial versus parallel processing issue may be valuable for understanding cerebral asymmetry. Therefore, to avoid potential problems which could be

attributed to methodological variables, the present experiment more closely followed Shatz's (1979) methodology than that of other research presented in the literature review.

Shatz (1979) performed three experiments in an endeavor to "bring some order to the currently chaotic findings in this field" (p. 14) and to evaluate cerebral laterality of serial and parallel processing, using both visual and auditory stimuli. The auditory stimuli in the first experiment consisted of memory sets and probe stimuli composed from a set of twenty-nine monosyllabic nouns. In the second experiment, memory set and probe stimuli were derived from a series of nine three-note chords. In each experiment, memory set items were presented binaurally to each ear at the same time. The probe stimulus was presented in only one ear on each trial, with white noise simultaneously presented to the other ear. By comparing reaction times to the probe stimuli presented to the left and right ears, Shatz could evaluate the processing strategy which was utilized by each cerebral hemisphere.

In the third experiment, information was presented to subjects via the visual modality. The memory set and probe stimuli were derived from an ordered set of nine sequential drawings which depicted a man diving off a diving board. These stimuli were adapted from DeRosa and Tkacz's (1976) experiment which investigated the effects of organization

of stimuli on reaction time. In the DeRosa and Tkacz experiment, these stimuli were presented to subjects in either a sequential or a random order. A random order of presentation was found to result in serial processing; when the items were ordered sequentially, parallel processing occurred. However, DeRosa and Tkacz did not investigate laterality of presentation (i.e., cerebral asymmetry). By using the DeRosa and Tkacz visual stimuli and by presenting the probe stimulus to the left or right visual half field, Shatz could determine if serial or parallel processing occurred within each cerebral hemisphere.

In all three experiments, Shatz observed serial reaction time curves for stimuli presented to the left cerebral hemisphere and parallel reaction time curves for stimuli presented to the right cerebral hemisphere. These results were obtained with both the auditory and the visual stimuli. In addition, the results of the third experiment indicated that the type of processing strategy within each cerebral hemisphere remained constant even though the stimuli had been arranged to facilitate serial or parallel processing. That is, items presented to the left hemisphere produced reaction time curves consistent with serial processing, regardless of whether the items were sequentially or randomly presented. Items presented to the right hemisphere resulted in reaction time curves consistent with parallel processing, regardless of whether the items were sequentially

or randomly presented.

On the basis of the results obtained in these experiments, Shatz (1979) proposed a structuralist model of hemispheric function. Shatz perceives the left cerebral hemisphere as being a serial processor of information and the right cerebral hemisphere as a parallel processor. This serial-parallel dichotomy is also implicitly referred to in the Goldberg and Costa (1981) model of cerebral asymmetry, as will be discussed in the next section.

Cerebral Asymmetry and Task Novelty

Goldberg and Costa (1981) also proposed a structural model to explain cerebral asymmetry. The basis of this model relies upon neuroanatomical differences between the two cerebral hemispheres. Investigation of these differences led Goldberg and Costa to propose two distinct neuroanatomical features. They reported, first of all, that "areas of sensory and motor representations are greater in the left hemisphere, while the right hemisphere is characterized by greater areas of associative cortex." Second, "the left hemisphere displays a predominantly intra-regional pattern of connectivity while the right hemisphere displays a predominantly inter-regional pattern of connections" (p. 148).

Goldberg and Costa related these neuroanatomical differences to distinctions in cognitive strategies between the cerebral hemispheres. They proposed that the right

cerebral hemisphere is superior "for situations for which no task-relevant descriptive system is immediately available in the subject's cognitive repertoire" (p. 154). The left cerebral hemisphere is superior for "any processing which utilizes a well routinized descriptive system" (p. 154). In other words, although the right cerebral hemisphere is dominant during the initial stages of acquisition of a novel task, the left cerebral hemisphere is dominant once the task has been fit into a previously "routinized descriptive system" or once a new descriptive system has been developed to accommodate the task. Thus, a further requirement of this model is the concept of a right-to-left shift of hemispheric dominance during acquisition of a novel task.

To support this model, Goldberg and Costa (1981) documented three categories of research. In the first category, research was included which demonstrated different patterns of hemispheric superiority in individuals who were at different levels of performance with respect to a particular cognitive skill. For example, research was reviewed in which a right ear (left hemisphere) advantage was demonstrated on dichotic listening tasks for trained musicians, while a left ear (right hemisphere) advantage was obtained for non-musicians (e.g., Bever & Chiarello, 1974; Johnson, 1977).

A second source of support for the model was derived from a review of studies which focused on the effects of

early brain injury on later cognitive development. Specifically, Goldberg and Costa examined research in which the right hemisphere was excluded from the learning process in the early stages of life. Evaluation of these individuals revealed an impairment in language acquisition (which is typically viewed as being a left hemisphere function), following a right hemisphere lesion sustained early in life.

The third source of experimental support, and the area of significance for the present experiment, was derived from research in which a shift from right-to-left hemispheric superiority was demonstrated during the acquisition of a skill. Experiments in this area have been presented by Gordon and Carmon (1976) and, more recently, by Bilder and Rosen (Note 1).

Gordon and Carmon (1976) tachistoscopically presented stimuli to the left or right visual field. Four types of number stimuli were used: familiar numbers; Gothic-like numbers; binary numbers presented in dot format; and symbols from the Digit Symbol test of the Wechsler Adult Intelligence Scale (Wechsler, 1955). The subjects' task was to recognize the numbers as quickly as possible. With the familiar numbers, a right visual field (left hemisphere) superiority was observed initially and remained throughout the session. For the other three types of stimuli, superiority in recognition was initially found in the left visual field (right hemisphere). However, over successive trials the superiority shifted to the right visual field.

Bilder and Rosen (Note 1) investigated accuracy of recognition and reaction time for angle stimuli which were tachistoscopically presented to the left or right visual field. They reported that accuracy of recognition increased, as a function of trials, for stimuli presented in the right visual field (left hemisphere). There was no significant change in accuracy of recognition with left visual field (right hemisphere) presentations. Bilder and Rosen concluded that a right-to-left shift of hemispheric superiority occurred as a result of practice. These articles, then, provide support for a right-to-left shift in hemispheric superiority during the course of learning a task as postulated by Goldberg and Costa (1981).

Purpose of the Present Experiment

The two models presented above provide an information-processing interpretation of cerebral asymmetry in opposition to localization of function. That is, the authors endeavoured to elucidate cognitive strategies rather than list the cognitive functions which have traditionally been associated with one or the other cerebral hemisphere. One model (Goldberg and Costa, 1981) focused on the concept of task novelty and representational codes to explain cerebral asymmetry; the other (Shatz, 1979) relied upon description of a specific processing strategy as determined by a reaction time measure.

There appears to be a similarity in the cognitive strategies presented in these models: they both either explicitly or implicitly propose that information is processed in a parallel manner within the right cerebral hemisphere and in a serial manner within the left cerebral hemisphere. These cognitive strategies are explicitly referred to by Shatz (1979) and are implicitly referred to by Goldberg and Costa (1981). That is, Goldberg and Costa depict the right cerebral hemisphere as having a greater neuronal capacity to process many modes of representation within a single cognitive task, which is related to its superiority for processing novel tasks. This strategy is analogous to a parallel processing strategy in which many comparisons can occur at one time. A parallel processing strategy would be more efficient with novel tasks because many aspects of the stimulus could be incorporated simultaneously. The left cerebral hemisphere is viewed by Goldberg and Costa as being superior for processing tasks which require fixation upon a single mode of representation or execution. This strategy is analogous to a serial processing strategy, whereby comparisons are made one at a time.

Comparison of these two models affords hypotheses for investigation. One hypothesis is as follows: A right hemisphere advantage with parallel processing should be obtained with a novel task and a left hemisphere advantage

with serial processing should be obtained with a familiar task. A second hypothesis is related to the effect of repeated exposure to an initially "novel" stimulus. Specifically, there should be a right-to-left shift in hemispheral superiority as a novel task becomes a familiar task, coincident with a change from a parallel to a serial processing strategy. The present experiment was designed to investigate these hypotheses.

The present experiment incorporated aspects of methodology utilized by both Goldberg and Costa (1981) and Shatz (1979). The independent variables included: stimulus familiarity, memory set size, laterality of probe, day of testing session, and polarity of probe. Visual stimuli were selected for tachistoscopic presentation to subjects on the basis of assumed familiarity or novelty of the stimuli. A "fixed-set" item recognition paradigm was included to differentiate serial and parallel memory scanning (Sternberg, 1969, 1975). Memory set size varied from two, three, or four items. If a linear increase in reaction time was obtained as a function of an increase in memory set size, a serial memory scan was assumed. If no significant linear increase in reaction time was obtained as a function of an increase in memory set size, a parallel memory scan was assumed.

Laterality of presentation of the probe stimulus was varied in order to investigate differences in processing information between the left and right cerebral hemisphere.

That is, when visual stimuli are tachistoscopically presented to one or the other visual field, it is assumed that processing occurs first in the cerebral hemisphere contralateral to the visual field of presentation. Differences obtained in reaction time are assumed to reflect hemispheral differences. Three days of testing were included in the experiment to ensure adequate time was available for initially novel stimuli to become familiar. Polarity of probe was included to investigate any differences in the dependent measures that might occur as a result of the probe stimulus being positive or negative.

The dependent measures utilized in this experiment included reaction time (in msec.) from onset of the probe stimulus to subjects' response and accuracy of discrimination (i.e., error data). Reaction time measures were used to differentiate serial and parallel processing strategies, defined by the presence or absence of a linear increase in reaction time as a function of an increase in memory set size for serial and parallel processing respectively. Reaction time measures were also used to indicate hemispheral superiority for processing stimuli; superiority defined by lower reaction time with presentation to one cerebral hemisphere in comparison to the other.

Accuracy of recognition was utilized as another measure of hemispheral superiority, defined by fewer errors obtained with presentation to one cerebral hemisphere in comparison

to the other. In addition, accuracy of discrimination data provided an indication of whether or not a right-to-left shift in hemispheral superiority occurred for processing novel stimuli. If this shift occurred, a significant decrease in errors with presentation to the left cerebral hemisphere should be obtained and no significant decrease in errors with presentation to the right cerebral hemisphere (Bilder and Rosen, Note 1).

Manipulation of the independent variables enabled investigation of the following predictions:

1. Reaction time curves for stimuli presented in the right visual field (left cerebral hemisphere) would be indicative of a serial processing strategy (i.e., there would be a significant linear increase in reaction time as a function of an increase in memory set size).
2. Reaction time curves for stimuli presented in the left visual field (right cerebral hemisphere) would be indicative of a parallel processing strategy (i.e., no significant linear increase in reaction time would be obtained as a function of an increase in memory set size).
3. In general, there would be a decrease in reaction time from day 1 to day 3. Reaction time obtained for familiar stimuli would be lower than that obtained for novel stimuli, although this difference would significantly decrease from day to day 3.

4. Over all days, reaction time for familiar stimuli would be lower with right visual field than left visual field presentation. This reaction time measure would indicate a left hemispheral superiority for processing familiar stimuli.
5. On day 1, reaction time for novel stimuli would be lower with left visual field than right visual field presentation. This reaction time measure would indicate right hemispheral superiority during the initial stages of processing novel stimuli. However, by day 3 the reverse effect would be obtained, coincident with a right-to-left shift in hemispheral superiority as novel stimuli become familiar.
6. In general, there would be a decrease in errors from day 1 to day 3. Fewer errors would be obtained with familiar stimuli in comparison to novel stimuli.
7. With familiar stimuli, a high level of accuracy of discrimination would be observed for stimuli presented to either cerebral hemisphere since subjects have had extensive experience with these stimuli. Therefore, a low error rate would be obtained, in comparison to novel stimuli, with both left and right visual field presentation of familiar stimuli over all 3 days of the experiment.
8. With novel stimuli, error data was also used to determine whether or not a right-to-left shift in hemispheral

superiority occurred. It was predicted that there would be a significant decrease in errors over day with right visual field presentation and no significant decrease in errors with left visual field presentation.

CHAPTER II

METHOD

Design

This experiment incorporated a 2 x 2 x 2 x 3 x 3 factorial design with repeated measures on all factors. The independent variables were: 1 stimulus familiarity, two levels (familiar and novel); 2 laterality of probe, two levels (left and right); 3 polarity of probe, two levels (positive and negative); 4 day of testing session, three levels (day 1, day 2, and day 3); 5 memory set size, three levels (two, three, or four digits/angles in a set).

The variables of stimulus familiarity, laterality of probe, memory set size, and day of testing session were incorporated into the design to enable investigation of the main predictions of the experiment as has been discussed in the Introduction. The experiment was continued over three days in order to ensure that subjects had sufficient time and experience with the "novel" angle stimuli so that they became "familiar" to enable investigation of the prediction of a right-to-left shift in hemisphere superiority. Pilot testing with three subjects indicated that, with the angle stimuli, level of performance reached a plateau on day 3 (i.e., no further notable decrease in reaction time or errors was observed between days 3 and 4 for two subjects

tested over 4 days, or between days 3 and 4 or 4 and 5 for one subject tested over 5 days. Polarity of probe was included to investigate any differences in reaction time that might occur as a result of type of response required (i.e., positive or negative). On the basis of previous research (e.g., Shatz, 1979), no such differences were anticipated.

The dependent variables in this study included a measure of reaction time (in msec.) from onset of the probe stimulus to subjects' response and a measure of accuracy of discrimination of the stimuli (i.e., error data).

Subjects

Fourteen male students selected from evening courses within the Psychology Department at the University of Windsor volunteered to participate in this experiment. Subjects' ranged in age from 19 to 44 years with a mean age of 24.14 years. All subjects were right-handed as determined by their responses to a hand preference questionnaire (Appendix A) reported by Coren and Porac (1978). On this questionnaire, 12 subjects endorsed all 8 items with a right hand response and 2 subjects endorsed 7 out of 8 items with a right hand response. All subjects had normal or corrected to normal vision. Subjects received course credit for participation in the experiment where appropriate. Subjects were apprised of the purpose of the experiment upon completion of all testing sessions.

Stimuli and Apparatus

Stimuli. "Novel" and "familiar" stimuli were selected in the following manner: digits were selected for presentation as familiar stimuli on the basis of assumed frequency of occurrence and use in everyday communication, and angles were selected as novel stimuli on the basis of assumed infrequency of occurrence and use in everyday communication. The familiar stimuli consisted of the digits from 1 to 9 printed in the typical Arabic script. The novel stimuli consisted of a set of nine angles which varied with respect to angle size (i.e., 30°, 60°, and 90°) and degree of rotation from a standard orientation of 0 degrees in a polar coordinate system (i.e., 0°, 90°, and 180°). The angle stimuli were adapted from those utilized by Bilder and Rosen (Note 1) who also defined these stimuli as "novel" during the early stages of presentation to subjects. Digit stimuli were constructed using Geotype (GS-108) 24 pt. Helvetica Medium Numerals, and angle stimuli consisted of black ink drawings on paper (Appendix B).

Five blocks of trials were constructed for each of three memory set sizes (Size = 2, 3, and 4) for both familiar and novel stimuli. Each trial block consisted of a memory set stimulus followed by 12 probe stimuli. Stimuli were randomly assigned as memory set items with the constraints that digits/angles could not be repeated within a memory set and that no memory set be replicated. Within

each trial block, there were 6 positive and 6 negative probe stimuli which were balanced across each visual field with the constraint that a particular visual field not receive more than three trials in succession.

The probe stimuli were presented 6° to the left or right of the midpoint of the viewing screen. For memory set size 2, each digit/angle appeared three times as a positive probe; for set size 3 each digit/angle appeared twice; and for set size 4 each digit/angle appeared at least once, with two of the stimuli randomly selected to appear twice. On the positive trials, the appearance of each digit/angle was divided between the two visual fields as equally as possible. On the negative trials, the digits/angles which did not appear in the memory set were selected and balanced within each visual field as equally as possible. The order of presentation of memory set size (i.e., Size = 2, 3, and 4) was randomly distributed within each of the familiar and novel conditions with the constraint that one of each memory set size appear in every 3 blocks of trials.

Apparatus. Stimulus slides consisted of black digits/angles photographed against a white background, and were rear-projected onto a 37 cm. by 37 cm. ground glass screen located in the center of a wooden frame (76 cm. in width, 60.5 cm. in height) using a Kodak 800 Carousel slide projector. An Electronic Tachistoscopic Shutter (Ralph Gerbrand Co., Model #G1165) was placed in front of the slide

projector to enable tachistoscopic presentation of the probe stimuli. A Lafayette Eight Band Program Timer (Model #52021) was used to control the time between presentation of slides on the carousel; timing on the Electronic Tachistoscopic Shutter; and a Hunter Model 120c timer which measured the subjects' reaction time in msec. Subjects indicated a positive or a negative response by pressing one of two labelled buttons located on a rectangular box (43.3 cm. in length; 25.4 cm. in width; and 10.2 cm. in height; with buttons positioned 14 cm. apart) placed in front of the subject. When a button was depressed, one of two lights on a monitor was illuminated, signalling either a positive or negative response visible only to the experimenter.

Subjects were seated at a table equipped with a B & L chin rest to maintain constant head position. The viewing distance from a subject's eyes to the center of the rear-projection screen was 1 meter.

Procedure

Each subject was tested over three consecutive days for approximately 2 hours each day. Attempts were made to schedule each subject for testing at approximately the same time on all three days, however, owing to conflicts in schedules, this arrangement was not always possible. The 2 hour time period represented approximately 10 minutes for instruction and sample items, 25-30 minutes for presentation

of familiar stimuli and 35-40 minutes for presentation of novel stimuli, including 2 planned breaks during each presentation. Approximately 5 minutes was required for adaptation to the room and adjustment of the chair and B & L headrest, and 5 minutes to complete the handedness questionnaire on the first day. On all 3 days, subjects were given up to 5 minutes to study each card depicting familiar and novel stimuli. In addition, on all 3 days subjects left the testing room for a 20-30 minute break between the presentation of familiar and novel stimuli.

All subjects received all 15 blocks of trials for both the familiar and novel stimuli on each day. The order in which subjects received the stimuli was counterbalanced across days. On the first day, half of the subjects were presented with all of the stimuli from the familiar set first, followed by the novel set; this order was reversed for the remaining subjects.

Prior to the presentation of familiar or novel stimuli, subjects received instructions concerning task requirements and were given 24 practice trials using stimulus items composed from letters of the alphabet to ensure that they understood the task. Similar instructions and the same general procedure was followed for the sample items as well as for familiar and novel stimuli. However, prior to presentation of the familiar and novel stimuli, subjects were allowed up to 5 minutes to study a card on which all

stimuli were depicted. The card was removed from view prior to presentation of the stimuli. Subject instructions were as follows:

> On the screen in front of you, you will be shown a series of slides on which these numbers/angles appear. First of all, you will be shown a slide which has either 2, 3, or 4 numbers/angles on it. I want you to look carefully at this slide and try to memorize the numbers/angles on it. Take as much time as you require to memorize this first slide in the set, and please indicate to me when you have done so. Then I want you to position your head in the chin rest and place the index fingers of each hand on the positive and negative buttons. I want you to focus your eyes on the dot in the center of the viewing screen and maintain that position for the series of 12 slides that will follow. Each slide will be flashed on the screen for a very brief period of time. These slides will have only one number/angle on each, and this number/angle will appear sometimes to the left and sometimes to the right of the center of the screen. Your task is to indicate whether the single number/angle was or was not in the set of 2, 3, or 4 numbers/angles that you memorized at the beginning of the set. If the single number/

angle was a member of the set, I want you to press the button marked "positive" with the index finger of your (left/right) hand. If the single number/angle was not a member of the set, I want you to press the button marked "Negative" with the index finger of your (left/right) hand. I want you to respond as quickly as you possibly can but with as few errors as possible. It is imperative that you keep your eyes fixed on that center dot while the slide series is presented in order to ensure that you perceive all the stimuli that are flashed. I will inform you when we have completed one set and are ready to start another one. Do you have any questions?

The button which was pressed to indicate a positive or a negative response was counterbalanced across subjects. Half of the subjects used their right hand to indicate a positive response and the left hand to signal a negative response; this order was reversed for the remaining subjects.

Each subject was allowed as much time as required to memorize the stimuli presented in each memory set. The duration of the probe stimuli was 100 msec., with an inter-trial interval of 4 sec. A series of breaks was planned after every 5 blocks of trials in order to ensure a subject's maximum level of performance throughout the testing session. Subjects were periodically asked at the end of the presentation of a set whether or not additional rest was required.

CHAPTER III

RESULTS

The results of the present experiment are examined in the following four sections. In the first section, results pertaining to analyses of reaction time data are presented. The second section focuses on analyses which were performed on error data. In the third section, analyses used to differentiate serial versus parallel processing are described. Finally, significant effects which were not directly related to the hypotheses of this experiment are reviewed.

Reaction Time Data

A histogram obtained on reaction time data (SAS procedure CHART, 1979) revealed that the distribution of scores was skewed towards the lower end of observed scores. Reaction time scores (measured in msec.) were subjected to a reciprocal transformation procedure (Winer, 1971) and the resulting distribution approximated a normal curve. The reciprocal scores were multiplied by a factor of 1000 in order to eliminate means beginning with zero which resulted from the reciprocal transformation procedure. A summary of means and standard deviations of transformed reaction time data by day, stimulus, memory set size, laterality, and

polarity is presented in Table 1.

Transformed reaction time data were subjected to an analysis of variance (ANOVA) for a 2 X 2 X 2 X 3 X 3 factorial design with repeated measures on all factors. These factors included stimulus familiarity, laterality of probe, polarity of probe, day of testing session, and memory set size. A summary of statistically significant results is presented in Table 2 and the complete ANOVA on transformed reaction time data is presented in Appendix C.

It was predicted that there would be an overall decrease in reaction time from day 1 to day 3. Inspection of mean reaction time by day (Table 1) reveals that there was a reduction in reaction time from day 1 to day 3. A significant main effect of day was obtained in the ANOVA ($F(2, 26) = 38.93$, $p < .0001$); comparisons between means indicated that this decrease in reaction time was statistically significant between days 1 and 2 and between days 2 and 3 ($p < .05$).[1] These findings provide support for the prediction of a decrease in reaction time over day.

It was predicted that reaction time for familiar stimuli would be lower in comparison to reaction time for novel stimuli. It was anticipated that this difference in reaction time between familiar and novel stimuli would become less over day. Means for familiar and novel stimuli as a function

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[1]These comparisons and all subsequent comparisons between means were tested by the Tukey (a) procedure (Winer, 1971).

Table 1

Means and standard deviations by day, stimulus, memory set size, laterality, and polarity for reaction time data

Variable	Transformed Data Mean	(S.D.)	Raw Data Mean	(S.D.)
Day				
Day 1	1.4088	(0.6137)	874.25	(465.65)
Day 2	1.5930	(0.6137)	742.98	(357.93)
Day 3	1.7115	(0.6233)	678.12	(302.44)
Stimulus				
Familiar	1.9134	(0.5709)	574.48	(198.05)
Novel	1.2288	(0.4816)	955.76	(438.54)
Memory Set Size				
Size = 2	1.7027	(0.6573)	693.53	(331.86)
Size = 3	1.5547	(0.6097)	765.69	(376.01)
Size = 4	1.4559	(0.5946)	836.14	(441.25)
Laterality				
Left Visual Field	1.5623	(0.6188)	766.06	(384.80)
Right Visual Field	1.5799	(0.6396)	764.18	(395.18)
Polarity				
Positive	1.6533	(0.6755)	733.54	(379.63)
Negative	1.4889	(0.5677)	796.70	(397.65)

Table 2

Summary of significant results obtained in analysis of variance on transformed reaction time data

Source	SS	df	MS	F	
Day	234.55	2	117.28	38.93	****
error	78.32	26	3.01		
Stim	1771.23	1	1771.23	219.70	****
error	104.81	13	8.06		
Size	155.48	2	77.74	118.56	****
error	17.05	26	0.66		
Size X Lat	2.18	2	1.09	6.76	**
error	4.19	26	0.16		
Stim X Size X Lat	0.43	2	0.22	4.25	*
error	1.33	26	0.05		
Pol	102.13	1	102.13	54.15	****
error	24.52	13	1.89		
Day X Pol	3.55	2	1.78	5.24	**
error	8.81	26	0.34		
Stim X Pol	9.98	1	9.98	12.97	***
error	9.99	13	0.77		
Stim X Size X Pol	1.47	2	0.74	4.62	*
error	4.13	26	0.16		

* $p < .05$
** $p < .01$
*** $p < .005$
**** $p < .0001$

of day are presented in Figure 2 and Table 3. Inspection of these means reveals that reaction time for familiar stimuli was lower than reaction time for novel stimuli on all 3 days.

The ANOVA revealed a significant main effect of stimulus ($F(1, 13) = 219.70$, $p < .0001$) and comparisons between means indicated that reaction time for familiar stimuli was significantly lower than reaction time for novel stimuli on all 3 days ($p < .05$). No significant day X stimulus interaction was obtained in the ANOVA, indicating that the difference in reaction time between familiar and novel stimuli did not significantly decrease over day. Additional comparisons between means revealed the reduction in reaction time for novel stimuli to be significant between days 1 and 2 and days 2 and 3 ($p < .05$). The decrease in reaction time for familiar stimuli was significant only between days 1 and 2 ($p < .05$). In summary, these findings provide support for the prediction of lower reaction time for familiar stimuli in comparison to novel stimuli. These findings do not support the prediction that this difference in reaction time between familiar and novel stimuli would become less over day.

Differences in hemispheral superiority for processing familiar and novel stimuli were anticipated. Hemispheral superiority was defined by significantly lower reaction time

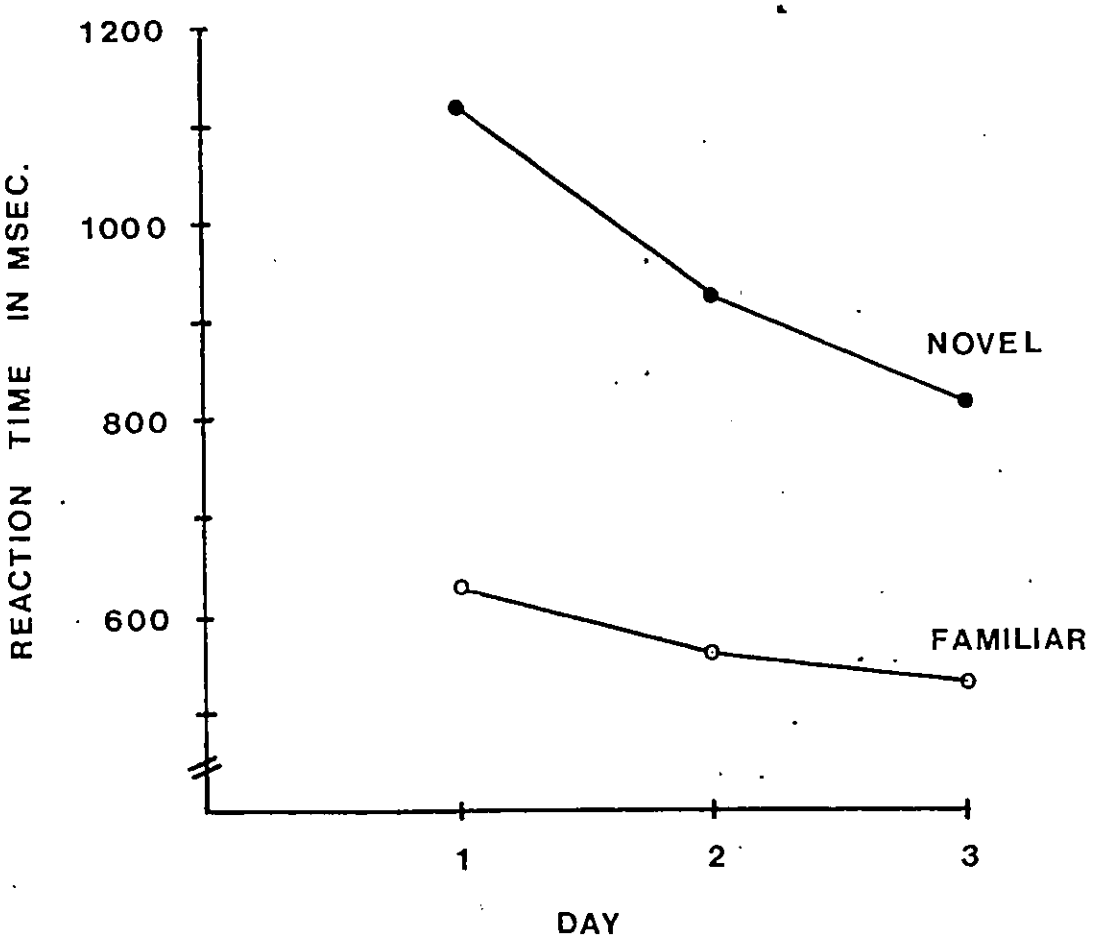


Figure 2. Mean raw reaction time for familiar and novel stimuli as a function of day

Table 3

Mean transformed reaction time for familiar and novel stimuli as a function of day, laterality, and day X laterality

	Stimulus			
	Familiar		Novel	
Variable	Mean	(S.D.)	Mean	(S.D.)
Day				
Day 1	1.7670	(0.5654)	1.0505	(0.4205)
Day 2	1.9469	(0.5498)	1.2392	(0.4479)
Day 3	2.0261	(0.5663)	1.3968	(0.5083)
Laterality				
Left Visual Field	1.8966	(0.5619)	1.2281	(0.4762)
Right Visual Field	1.9302	(0.5793)	1.2296	(0.4870)
Day X Laterality				
Left Visual Field				
Day 1	1.7480	(0.5433)	1.0588	(0.4247)
Day 2	1.9346	(0.5484)	1.2383	(0.4457)
Day 3	2.0071	(0.5621)	1.3871	(0.4975)
Right Visual Field				
Day 1	1.7861	(0.5864)	1.0422	(0.4164)
Day 2	1.9592	(0.6510)	1.2400	(0.4503)
Day 3	2.0452	(0.5700)	1.4066	(0.5189)

Note. Means are based on transformed reaction time data (reciprocal transformation); therefore increasing values represent decreasing reaction time.

for stimuli presented to one visual field in comparison to the other. With respect to familiar stimuli, it was predicted that reaction time would be lower with right visual field presentation. Examination of means for familiar stimuli for left and right visual field presentation (Table 3) indicated that reaction time was lower with right visual field presentation on all three days. Comparisons between means revealed this difference to be significant on all 3 days ($p < .05$). These findings support the prediction of a right visual field (left cerebral hemisphere) superiority for processing familiar stimuli.

With respect to novel stimuli, it was predicted that reaction time would initially be lower (on day 1) with left visual field than right visual field presentation. However, over 3 days of testing these reaction time measures were expected to reverse, indicating a right visual field advantage for processing novel stimuli. Although the differences between left and right visual field presentation were in the predicted direction on day 1 and day 3 (Table 3), comparisons between means revealed that these differences were not significant for any day of testing. Consequently, there was no opportunity to observe a subsequent right-to-left shift in hemispheral superiority for processing novel stimuli with reaction time data.

Error Data

An error was recorded whenever a subject gave an incorrect response to a probe stimulus (i.e., pressing the "positive" button to a negative probe or the "negative" button to a positive probe). Each error was assigned a numeric value of "1" and correct responses were assigned a value of "0".

The error rate observed in the present experiment is consistent with previous research. The overall error rate was 1.9% for familiar stimuli and 9.8% for novel stimuli. These error rates correspond to previous research utilizing the memory scanning paradigm, where the error rate ranged from 1.4% (Klatzky & Atkinson, 1971) to 16.8% (Cohen, 1973).

A summary of means and standard deviations for error data by day, stimulus, memory set size, laterality, and polarity is presented in Table 4. Error data were subjected to an analysis of variance for a 2 X 2 X 2 X 3 X 3 factorial design with repeated measures on all factors. These factors included stimulus familiarity, laterality of probe, polarity of probe, day of testing session, and memory set size. A summary of statistically significant results is presented in Table 5 and the complete ANOVA for error data is presented in Appendix D.

It was predicted that there would be an overall decrease in number of errors from day 1 to day 3. Inspection of mean errors by day (Table 4) reveals that there was a reduction

Table 4

Means and standard deviations by day, stimulus, memory set size, laterality, and polarity for error data

Variable	Mean	(S.D.)
Day		
Day 1	0.0823	(0.2749)
Day 2	0.0554	(0.2287)
Day 3	0.0375	(0.1900)
Stimulus		
Familiar	0.0193	(0.1376)
Novel	0.0975	(0.2966)
Memory Set Size		
Size = 2	0.0403	(0.1966)
Size = 3	0.0577	(0.2333)
Size = 4	0.0772	(0.2669)
Laterality		
Left Visual Field	0.0643	(0.2453)
Right Visual Field	0.0525	(0.2231)
Polarity		
Positive	0.0671	(0.2501)
Negative	0.0497	(0.2174)

Table 5

Summary of significant results obtained in analysis of variance on error data

Source	SS	df	MS	F
Day	5.14	2	12.57	19.74 ****
error	3.38	26	0.13	
Stim	23.10	1	23.10	26.60 ***
error	11.29	13	0.87	
Day X Stim	3.74	2	1.87	14.68 ****
error	3.32	26	0.13	
Size	3.44	2	1.72	12.71 ****
error	3.51	26	0.14	
Stim X Size	1.68	2	0.84	7.77 **
error	2.81	26	0.11	
Day X Stim X Size	0.61	4	0.15	2.66 *
error	3.00	52	0.06	
Lat	0.52	1	0.52	7.81 *
error	0.87	13	0.07	
Pol	1.13	1	1.14	8.35 **
error	1.77	13	0.14	
Stim X Pol	1.00	1	1.00	9.69 **
error	1.34	13	0.10	
Lat X Pol	0.28	1	0.28	6.61 *
error	0.55	13	0.04	

* $p < .05$
** $p < .01$
*** $p < .001$
**** $p < .0001$

in errors over day. A significant main effect of day was obtained in the ANOVA ($F(2, 26) = 19.74$, $p < .0001$). Comparisons between means indicated that this decrease in errors was significant between days 1 and 2 and between days 2 and 3 ($p < .05$). These findings provide support for the prediction of a decrease in errors over day.

It was predicted that fewer errors would be obtained with presentation of familiar stimuli in comparison to novel stimuli. Inspection of mean errors for familiar and novel stimuli (Table 4) reveals that there were fewer errors for familiar stimuli. A significant main effect of stimulus ($F(1, 13) = 26.20$, $p < .001$) provided support for this prediction. Additional comparisons between mean errors for familiar and novel stimuli by day (Table 6) revealed that there were significantly fewer errors for familiar stimuli on all 3 days of presentation ($p < .05$).

The error rate for familiar stimuli was not expected to vary over day, while a significant decrease in errors was predicted for novel stimuli. Mean errors by day for familiar and novel stimuli are presented in Table 6 and Figure 3. Examination of these means reveals a notable reduction in errors over day only for novel stimuli. A significant day X stimulus interaction was found ($F(2, 26) = 14.68$, $p < .0001$) and analysis of simple effects indicated that there was a significant decrease in errors over day only for novel stimuli ($F(2, 52) = 34.23$, $p < .001$). Comparisons between

Table 6

Mean errors for familiar and novel stimuli as a function of day, laterality, and day X laterality

Variable	Stimulus: Familiar Mean	Familiar (S.D.)	Novel Mean	Novel (S.D.)
Day				
Day 1	0.0234	(0.1512)	0.1413	(0.3484)
Day 2	0.0175	(0.1310)	0.0933	(0.2908)
Day 3	0.0171	(0.1295)	0.0579	(0.2337)
Laterality				
Left Visual Field	0.0270	(0.1621)	0.1016	(0.3021)
Right Visual Field	0.0116	(0.1073)	0.0934	(0.2910)
Day X Laterality				
Left Visual Field				
Day 1	0.0262	(0.1598)	0.1508	(0.3580)
Day 2	0.0286	(0.1667)	0.0921	(0.2892)
Day 3	0.0262	(0.1598)	0.0619	(0.2411)
Right Visual Field				
Day 1	0.0206	(0.1422)	0.1317	(0.3383)
Day 2	0.0063	(0.0795)	0.0944	(0.2926)
Day 3	0.0079	(0.0888)	0.0540	(0.2260)

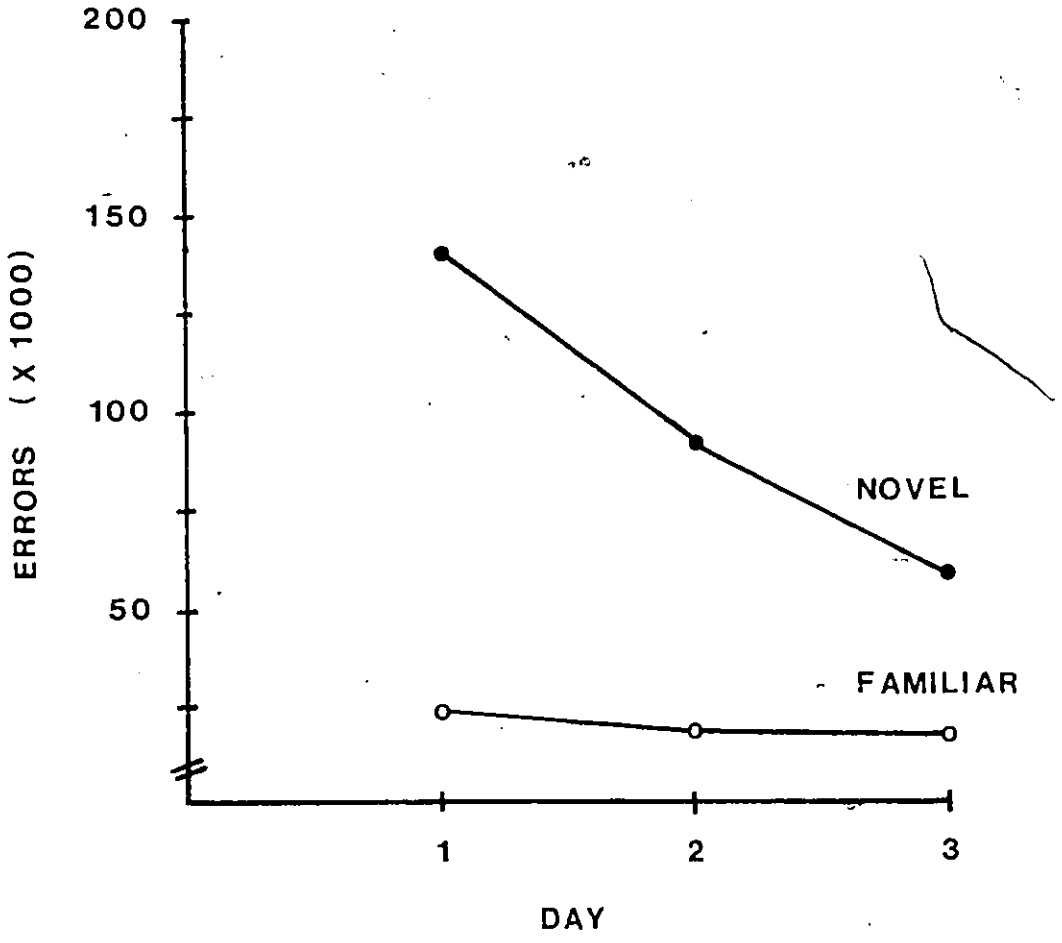


Figure 3. Mean errors for familiar and novel stimuli as a function of day

means indicated that this decrease in errors was significant between days 1 and 2 and between days 2 and 3 ($p < .05$). No significant change in error rate over day was found for familiar stimuli. These findings support the prediction of a differential decrease in errors over day for familiar and novel stimuli.

Differences in hemispheral superiority, defined by significantly fewer errors for stimuli presented to one visual field in comparison to the other, were anticipated. The ANOVA on error data revealed a significant main effect of laterality ($F(1, 13) = 7.81$, $p < .05$) which indicated that there were fewer errors overall with right visual field presentation than with left visual field presentation.

With respect to familiar stimuli, it was predicted that there would be no difference in error rate between left and right visual field presentation. Comparisons of mean errors for left and right visual field presentation summed across day (Table 6) revealed that there were significantly fewer errors with right visual field presentation ($p < .05$). At each day there were fewer errors with right visual field presentation (Table 6), although this difference was statistically significant only at day 2 ($p < .05$). These findings do not support the prediction of no difference in error rate between left and right visual field presentation for familiar stimuli; fewer errors were obtained with right visual field presentation.

With respect to novel stimuli, it was predicted that there would be a significant decrease in errors over day with right visual field presentation and no decrease in errors over day with left visual field presentation. Mean errors for novel stimuli by day and laterality are presented in Table 6. Comparisons between means for novel stimuli indicated that, for both left and right visual field presentations, there was a significant decrease in errors between days 1 and 2 and days 2 and 3 ($p < .05$). Thus, these findings do not appear to support the hypothesis of a right-to-left shift in hemispheral superiority for processing novel stimuli utilizing the measure suggested by Bilder and Rosen (Note 1).

In addition, there did not appear to be a consistent pattern of errors attributable to laterality of presentation. Fewer errors were found on days 1 and 3 with right visual field presentation and fewer errors on day 2 with left visual presentation. Comparisons between means revealed that there were no significant differences in error rate between left and right visual field presentations on any day of testing.

Serial versus Parallel Processing

A main hypothesis of the present experiment concerned differential memory scanning between the left and right cerebral hemispheres. Specifically, it was predicted that

reaction time curves for stimuli presented to the left cerebral hemisphere would be indicative of a serial processing strategy, defined by a significant linear increase in reaction time as a function of an increase in memory set size. It was predicted that reaction time curves for stimuli presented to the right cerebral hemisphere would be indicative of a parallel processing strategy, defined by no significant linear increase in reaction time as a function of an increase in memory set size. A summary of means for laterality X set size for familiar and novel stimuli is presented in Table 7. Figures 4 and 5 present mean reaction time in msec. for left and right visual field presentation as a function of memory set size, for familiar and novel stimuli respectively.

Examination of means for familiar and novel stimuli as a function of laterality and set size (Table 7 and Figures 4 and 5) indicates that there was an increase in reaction time as a result of an increase in memory set size with both left and right visual field presentation. A significant stimulus X size X laterality interaction was obtained in the ANOVA on reaction time data ($\underline{F}(2, 26) = 4.25$, $p < .05$). Analysis of simple effects of this interaction revealed this effect of set size to be signif[illegible] for familiar and novel stimuli with left and right [illegible] field presentation [familiar, left visual field ($\underline{F}(2, 91) = 54.37$, $p < .001$); familiar, right visual field ($\underline{F}(2, 91) = 82.11$, $p < .001$); novel,

Table 7

Mean transformed reaction time for familiar and novel stimuli as a function of laterality X set size

	Stimulus			
	Familiar		Novel	
Variable	Mean	(S.D.)	Mean	(S.D.)
Laterality X Set Size				
Left Visual Field				
Size = 2	2.0099	(0.5968)	1.3496	(0.4925)
Size = 3	1.8933	(0.5482)	1.2290	(0.4614)
Size = 4	1.7866	(0.5157)	1.1056	(0.4420)
Right Visual Field				
Size = 2	2.0847	(0.6195)	1.3665	(0.5180)
Size = 3	1.8832	(0.5565)	1.2133	(0.4685)
Size = 4	1.8226	(0.5254)	1.1089	(0.4365)

Note. Means are based on transformed reaction time data (reciprocal transformation); therefore increasing values represent decreasing reaction time.

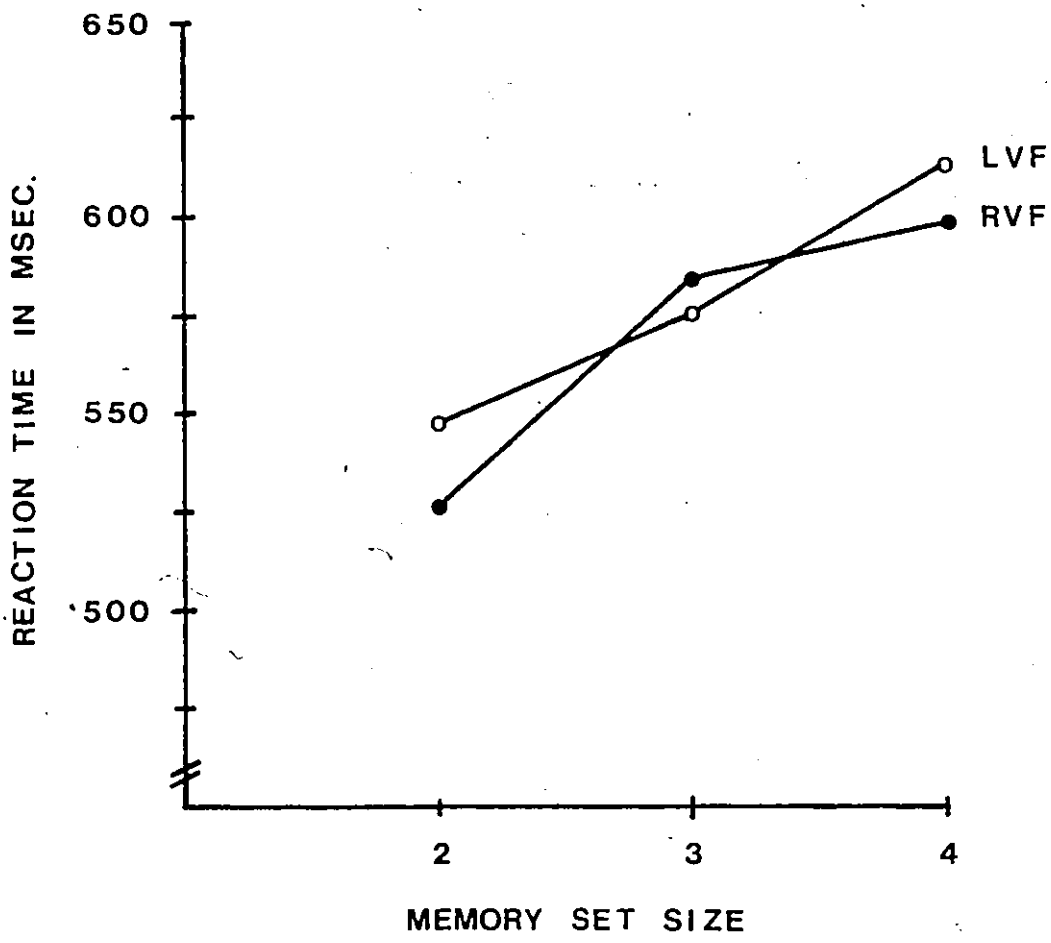


Figure 4. Mean raw reaction time for familiar stimuli as a function of laterality and memory set size

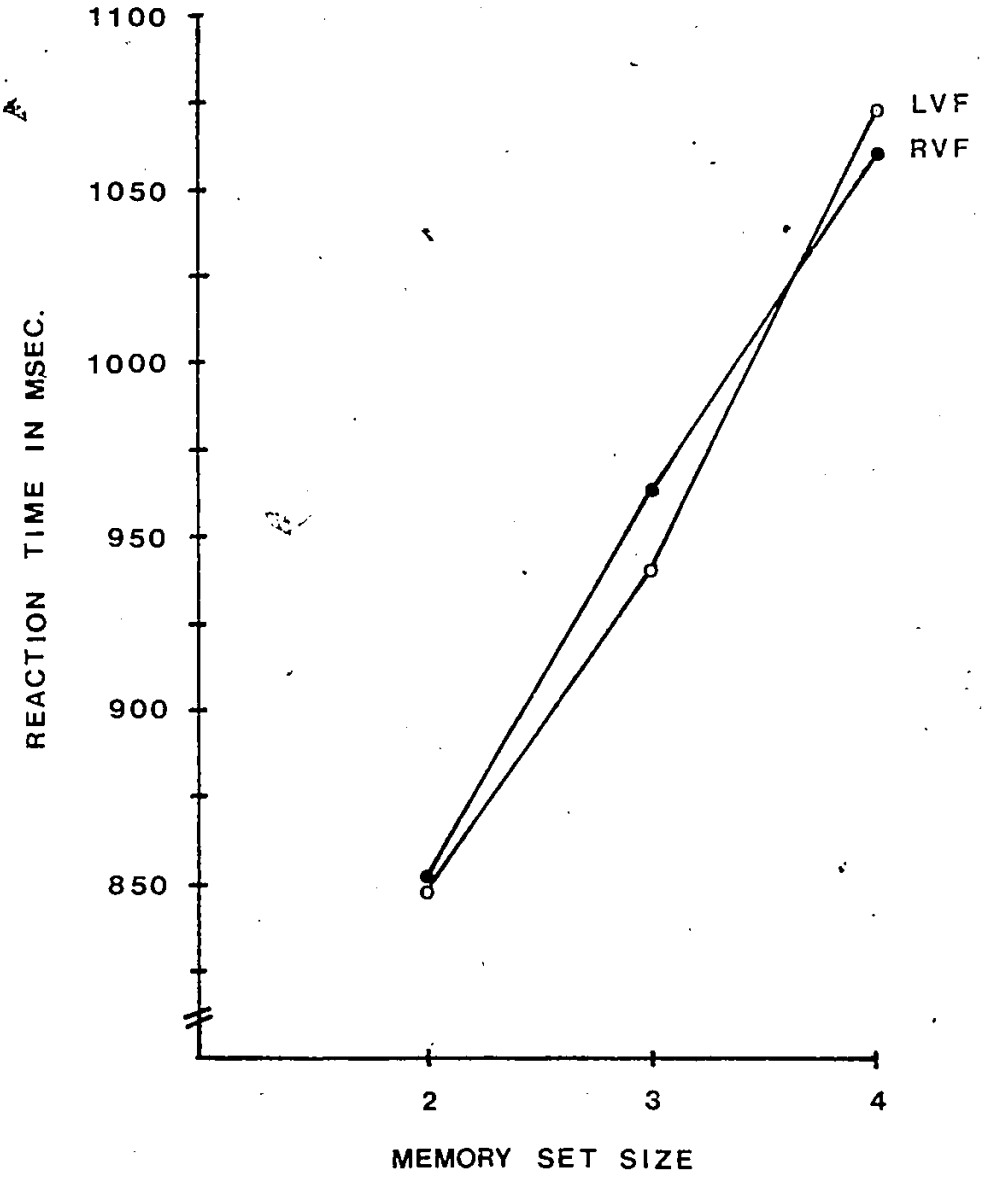


Figure 5. Mean raw reaction time for novel stimuli as a function of laterality and memory set size

left visual field ($F(2, 91) = 64.91$, $p < .001$; novel, right visual field ($F(2, 91) = 73.20$, $p < .001$)]. Comparisons between means indicated that the increase in reaction time was significant between set size 2 and 3 and set size 3 and 4 for familiar and novel stimuli with left and right visual field presentation ($p < .05$).

Trend analyses of these reaction time data were done to further evaluate the increase in reaction time as a function of an increase in memory set size. A summary of these results is presented in Table 8. Transformed reaction time data were not used in these analyses as the reciprocal transformation would not allow non-linear trends to emerge.

Trend analyses revealed significant linear components with both left and right visual field presentation for familiar and novel stimuli. No significant quadratic components were obtained in the analyses (Table 8). These linear trends are notably larger for novel stimuli as indicated by greater sums of squares and a more rapid increase in reaction time per unit increase in memory set size (i.e., comparison of Figures 4 and 5). In summary, these findings may be consistent with a serial memory scan in both the left and right cerebral hemispheres (i.e., there is a significant linear increase in reaction time as a function of an increase in memory set size). Thus, the findings of the present experiment do not support the hypothesis of differential memory scanning between the left and right cerebral hemispheres.

Table 8

Summary of trend analysis on set size X stimulus X laterality interaction (raw reaction time data)

Source	SS	df	MS	F
Set Size (Linear)				
Familiar, LVF	2736102.1	1	2736102.1	18.01 *
Familiar, RVF	3377008.9	1	3377008.9	22.23 *
Novel, LVF	31585349.0	1	31585349.0	207.87 *
Novel, RVF	27103862.0	1	27103862.0	178.38 *
Set Size (Quadratic)				
Familiar, LVF	22755.2	1	22755.2	1
Familiar, RVF	379652.6	1	379652.6	2.50
Novel, LVF	341757.8	1	341757.8	2.25
Novel, RVF	47680.9	1	47680.9	1
error	15802355.0	104	151945.72	

* $p < .001$

Subsidiary Analysis

In this section, significant effects which were obtained in analyses of reaction time and error data but were not germane to the hypotheses of the present experiment are reviewed. These findings include the effect of memory set size on error rate, and the effects of polarity of probe on both error rate and reaction time.

No difference in error rate was anticipated as a function of memory set size. However, the ANOVA on error data revealed a significant main effect of set size ($F(2, 26) = 12.71$, $p < .0001$) which indicated that number of errors increased as a result of an increase in memory set size. Comparison of means (Table 4) revealed that this increase in errors was significant only between set size 2 and 3 ($p < .05$).

Memory set size appeared to have a differential effect on error rate for familiar and novel stimuli. A significant day X stimulus X size interaction was obtained in the ANOVA on error data ($F(4, 52) = 2.66$, $p < .05$). Analysis of simple main effects of this interaction indicated that there was a significant increase in errors as a function of an increase in memory set size only for novel stimuli at day 1 ($F(2, 156) = 23.29$, $p < .001$) and day 2 ($F(2, 156) = 12.55$, $p < .001$).

Means for familiar and novel stimuli as a function of set size and day X set size are presented in Table 9. Comparison of mean errors for familiar stimuli revealed no

Table 9

Mean errors for familiar and novel stimuli

as a function of set size and day X set size

	Stimulus			
	Familiar		Novel	
Variable	Mean	(S.D.)	Mean	(S.D.)
Set Size				
Size = 2	0.0139	(0.1171)	0.0667	(0.2495)
Size = 3	0.0190	(0.1367)	0.0964	(0.2952)
Size = 4	0.0250	(0.1562)	0.1294	(0.3357)
Day X Set Size				
Day 1				
Size = 2	0.0167	(0.1281)	0.1000	(0.3002)
Size = 3	0.0238	(0.1525)	0.1321	(0.3388)
Size = 4	0.0298	(0.1700)	0.1917	(0.3938)
Day 2				
Size = 2	0.0179	(0.1325)	0.0571	(0.2323)
Size = 3	0.0119	(0.1085)	0.0976	(0.2970)
Size = 4	0.0226	(0.1488)	0.1250	(0.3309)
Day 3				
Size = 2	0.0071	(0.0843)	0.0429	(0.2027)
Size = 3	0.0214	(0.1449)	0.0595	(0.2367)
Size = 4	0.0226	(0.1488)	0.0714	(0.2577)

significant change in error rate attributable to memory set size. Comparison of means for novel stimuli indicated that the increase in errors was significant between set size 2 and 3 and between set size 3 and 4 ($p < .05$). Comparison of mean errors for novel stimuli at each day of testing revealed a significant increase in errors between set size 2 and 3 and set size 3 and 4 at day 1, and between set size 2 and 3 at day 2 ($p < .05$). No statistically significant increase in error rate attributable to memory set size was obtained on day 3.

Polarity of probe (i.e., whether the probe stimulus was positive or negative) was not expected to affect reaction time or error rate. However, significant effects attributable to polarity were found in analyses of reaction time and error data. A summary of these findings and additional analyses concerning polarity of probe will be presented.

The ANOVA on error data revealed a significant main effect of polarity ($F(1, 13) = 8.35$, $p < .01$) which indicated that there were more errors overall when the probe stimulus was positive than when it was negative (Table 4). Polarity of probe appeared to have a differential effect for familiar and novel stimuli (Table 10). A significant stimulus X polarity interaction was obtained in the ANOVA on error data ($F(1, 13) = 9.69$, $p < .01$). Analysis of simple main effects revealed that there were significantly more errors to the positive probe than to the negative probe only for novel

Table 10

Mean errors for polarity of probe as a function of stimulus and laterality

	Polarity of Probe			
	Positive		Negative	
Variable	Mean	(S.D.)	Mean	(S.D.)
Stimulus				
Familiar	0.0198	(0.1395)	0.0188	(0.1358)
Novel	0.1143	(0.3182)	0.0807	(0.2724)
Laterality				
Left Visual Field	0.0772	(0.2670)	0.0513	(0.2207)
Right Visual Field	0.0569	(0.2316)	0.0481	(0.2141)

stimuli ($F(1, 26) = 17.83$, $p < .001$).

Polarity of probe was also found to have a differential effect on error rate as a function of visual field of presentation (Table 10). The ANOVA on error data revealed a significant laterality X polarity interaction ($F(1, 13) = 6.61$, $p < .05$). Analysis of simple main effects indicated that there were significantly more errors to the positive probe than to the negative probe only for left visual field presentation ($F(1, 26) = 14.36$, $p < .001$).

Significant effects attributable to polarity of probe were also obtained in analyses of reaction time data. There was a significant main effect of polarity ($F(1, 13) = 54.15$, $p < .0001$) which indicated that reaction time was faster to the positive probe than to the negative probe (Table 1). A significant day X polarity interaction was also found in the ANOVA for reaction time data ($F(1, 13) = 5.24$, $p < .01$). Analysis of simple main effects revealed that reaction time was significantly faster to the positive probe than to the negative probe on each day of testing [polarity at day 1 ($F(1, 39) = 23.11$, $p < .001$); polarity at day 2 ($F(1, 39) = 41.56$, $p < .001$); polarity at day 3 ($F(1, 39) = 58.99$, $p < .001$)].

A significant stimulus X set size X polarity interaction was obtained in the ANOVA for reaction time data ($F(2, 26) = 4.62$, $p < .05$). Examination of means for polarity of probe by stimulus and memory set size (Table 11, Figure 6)

Table 11

Mean transformed reaction time for polarity of probe as a function of day, stimulus, and stimulus X memory set size

	Polarity of Probe			
	Positive		Negative	
Variable	Mean	(S.D.)	Mean	(S.D.)
Day				
Day 1	1.4714	(0.6533)	1.3462	(0.5645)
Day 2	1.6770	(0.6615)	1.5091	(0.5493)
Day 3	1.8115	(0.6678)	1.6115	(0.5578)
Stimulus				
Familiar	2.0212	(0.6078)	1.8055	(0.5090)
Novel	1.2853	(0.5219)	1.1723	(0.4303)
Stimulus X Set Size				
Familiar				
Size = 2	2.1550	(0.6236)	1.9395	(0.5750)
Size = 3	1.9901	(0.6083)	1.7863	(0.4684)
Size = 4	1.9185	(0.5661)	1.6906	(0.4430)
Novel				
Size = 2	1.3866	(0.5511)	1.3296	(0.4535)
Size = 3	1.2856	(0.5064)	1.1567	(0.4095)
Size = 4	1.1838	(0.4867)	1.0307	(0.3704)

Note. Means are based on transformed reaction time data (reciprocal transformation); therefore increasing values represent decreasing reaction time.

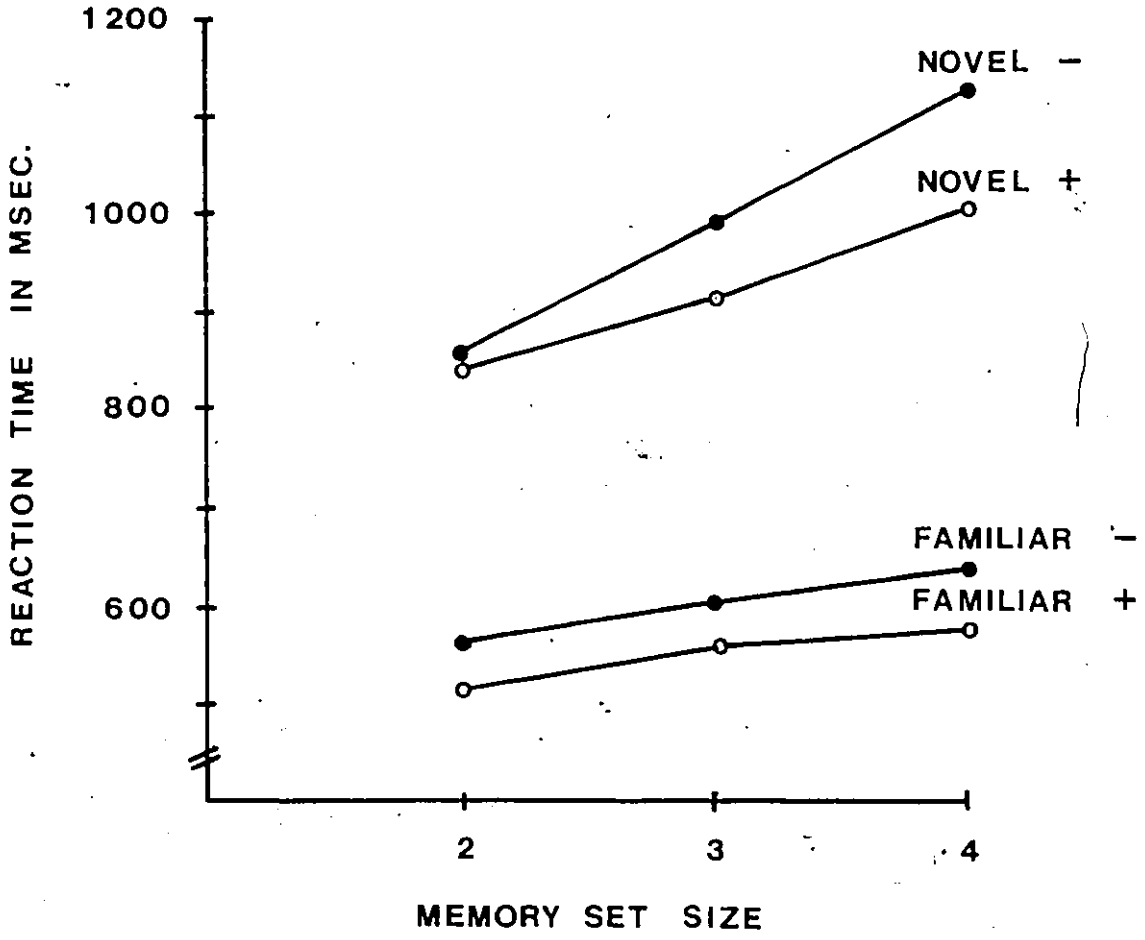


Figure 6. Mean raw reaction time for familiar and novel stimuli as a function of polarity of probe and memory set size

suggested that reaction time was faster to the positive probe than to the negative probe at all levels of memory set size. Analysis of simple main effects of this interaction revealed that for familiar stimuli, reaction time was significantly faster to the positive probe at all levels of memory set size. For novel stimuli, reaction time was significantly faster to the positive probe only at set size 3 and 4 (Appendix E).

Of notable interest in this data is the observation of a differential increase in reaction time for positive and negative probes as a function of an increase in memory set size for familiar and novel stimuli (Figure 6). That is, with respect to familiar stimuli, there is no apparent difference in the rate of increase in reaction time per unit increase in memory set size for positive and negative probes. Regression analysis revealed a similar rate of increase for positive and negative probes: the increase in reaction time per unit increase in set size was 31.3 msec. for the positive probe and 38.5 msec. for the negative probe. The rate of increase for the positive probe was 80% of that for the negative probe, and the difference was not significant as no set size X polarity interaction was obtained for familiar stimuli.

For novel stimuli, there appeared to be a differential increase in reaction time per unit increase in memory set size attributable to polarity of probe. There was a signi-

ficant difference between positive and negative probes as a function of memory set size (as indicated by the set size X polarity interaction for novel stimuli). Regression analysis revealed that the rate of increase in reaction time per unit increase in memory set size was 134.4 msec. for the negative probe and 81.3 msec. for the positive probe. The rate of increase for the positive probe is 60% of that for the negative probe. These findings indicate that, for novel stimuli, there was a differential effect of polarity of probe on the increase in reaction time observed as a function of an increase in memory set size.

CHAPTER IV

DISCUSSION

The findings of the present experiment will be reviewed in the following manner. First, the results will be summarized with respect to whether or not they provided support for the hypotheses of the present experiment. Second, the relationship of the results obtained in the present experiment with previous research will be discussed. Finally, suggestions for future research will be proposed.

Summary of Results

The central focus of the present experiment was cerebral asymmetry. Hypotheses for investigation were derived from comparison of two recent models which provided an information-processing interpretation of cerebral asymmetry. One model (Goldberg & Costa, 1981) accounted for cerebral asymmetry on the basis of task novelty and encodability of stimuli. The second model (Shatz, 1979) proposed that cerebral asymmetry was related to the type of memory scanning strategy utilized in the left and right cerebral hemisphere.

One hypothesis of the present experiment stated that "A right hemisphere advantage with parallel processing should

be obtained with a novel task and a left hemisphere advantage with serial processing should be obtained with a familiar task." A second hypothesis concerned the effects of repeated exposure to an initially novel stimulus. Specifically, the second hypothesis stated that "There should be a right-to-left shift in hemispheral superiority as a novel task becomes a familiar task, coincident with a change from a parallel to a serial processing strategy." The results of the present experiment will be reviewed as they pertain to these hypotheses.

In order to evaluate the support for these hypotheses, it must first be determined if there were any differences in hemispheral superiority for processing familiar and novel stimuli. With respect to familiar stimuli, a right visual field advantage was observed in both reaction time and error data. That is, reaction time was significantly lower and significantly fewer errors were obtained with right visual field presentation. These findings indicate that there was a left hemispheral superiority for processing familiar stimuli, as had been predicted.

With respect to novel stimuli, no significant difference in reaction time or error rate was observed between left and right visual field presentation. These findings indicate that there was no initial left visual field (right hemisphere) advantage for processing novel stimuli. Consequently, there was no opportunity to observe a subse-

quent right-to-left shift in hemispheral superiority for processing novel stimuli, as had been predicted.

Evaluation of the memory scanning strategies was contingent upon distinguishing between the processing methods. A further requirement for differentiation of serial and parallel processing was the observation of different reaction time curves for left and right visual field presentation. Results of the present experiment indicated that, with both left and right visual field presentations, there was a significant linear increase in reaction time as a function of an increase in memory set size. Thus, there were no apparent differences in memory scanning strategy between the left and right cerebral hemispheres.

The results obtained with respect to the serial-parallel dichotomy and laterality differences were inconclusive. That is, on the basis of Sternberg's (1969, 1975) definition of serial and parallel processing, it is accepted that, if different reaction time curves are obtained for left and right visual field presentation, different processing strategies are indicated. However, in the absence of differential reaction time curves, it becomes difficult to distinguish serial and parallel processing (Shatz, 1979; Townsend, 1972). Thus, within the present experiment, serial and parallel processing could not be differentiated since reaciton time curves were similar for both left and right visual field presentation.

In summary, the hypotheses of the present experiment were only partially supported. There was a left hemispheral superiority obtained for processing familiar stimuli. However, no initial right hemispheral superiority for processing novel stimuli was observed. Consequently, the hypothesis of a right-to-left shift in hemispheral superiority for processing novel stimuli could not be evaluated. The hypothesis concerning differential memory scanning between the left and right cerebral hemispheres could not be evaluated since serial and parallel processing could not be differentiated on the basis of the findings obtained in the present experiment.

Several additional predictions were made as a consequence of the main hypotheses of the present experiment, but were not directly relevant to these hypotheses. The results of the present experiment with respect to these predictions will now be addressed.

It was anticipated that there would be differences in reaction time and error rate between stimulus items selected and defined as "familiar" and "novel." The majority of these predictions were supported. There was an overall superiority observed for processing familiar stimuli in comparison to novel stimuli, as indicated by significantly lower reaction time and fewer errors obtained on all three days. However, the <u>difference</u> in reaction time between familiar and novel stimuli did not become significantly less

by day 3, as had been predicted. These findings indicate that there was a distinction between stimuli classified as familiar and novel which was maintained throughout the course of the experiment.

Several predictions pertained to changes in performance over time, and all of these predictions were supported. There was a decrease in reaction time over day for both familiar and novel stimuli, suggesting the presence of learning and practice effects. For novel stimuli, reaction time decreased significantly on all three days. For familiar stimuli, a plateau in performance was obtained by day 2. Although these findings suggest that the difference between familiar and novel stimuli diminished over day, this decrease was not statistically significant as indicated by the absence of a day X stimulus interaction.

As predicted, no significant decrease in errors was obtained over day for familiar stimuli: the error rate remained low, which may suggest the presence of a baseline effect in accuracy of recognition of these stimuli. There was a significant decrease in errors over day for novel stimuli, suggesting the continued presence of learning and practice effects with respect to accuracy of recognition.

Relationship of Present Findings to Previous Research

The findings of the present experiment were consistent in some respects with those reported in the literature on

cerebral asymmetry. For example, the right visual field (left hemisphere) superiority that was observed for digits (i.e., familiar stimuli) corresponds with previous research on laterality differences and with that expected on the basis of Goldberg and Costa's (1981) model. However, the observation of no difference in hemispheral superiority for angle stimuli (i.e., novel stimuli) is not consistent with previous research or with Goldberg and Costa's (1981) model.

The lack of hemispheral superiority for processing novel stimuli may be related to differences in methodology between the present experiment and previous research. The angle stimuli were adapted from those utilized in a study which did provide support for the Goldberg and Costa (1981) model. However, in this experiment (Bilder & Rosen, Note 1) subjects were only required to match a single target to a standard stimulus on each trial. In the present experiment, incorporating these stimuli within the framework of the memory scanning paradigm changed the task requirements and may have influenced the manner in which subjects perceived these stimuli. It is suggested that the task requirements in the present experiment were more difficult than those in the Bilder and Rosen (Note 1) experiment. Furthermore, memory set sizes were not of equivalent difficulty for angle stimuli as indicated by a significant increase in errors as a function of an increase in memory set size. At the present time, the relationship between task difficulty and

task novelty is not clearly defined. That is, Goldberg and Costa (1981) discussed the variable of "informational complexity" in reference to novel stimuli but did not address the issue of level of difficulty of a task.

With respect to the observation of an increase in errors as a function of an increase in memory set size for novel stimuli, it is important to note that, in previous research, memory set sizes which were not of equivalent difficulty were excluded from evaluation of serial versus parallel processing (e.g., Cohen, 1973, Shatz, 1979). This procedure was not followed in the present experiment. It was felt that if the increase in difficulty confounded the increase in reaction time as a function of an increase in memory set size, then significant quadratic components would be obtained. That is, it was expected that the difference in reaction time between memory set size 3 and 4 would be much greater than between memory set size 2 and 3. These findings were not obtained in the present experiment as no significant non-linear components were observed (e.g., Table 8).

The observation of no hemispheral superiority for novel stimuli may also be related to the amount of time which was allotted for these stimuli to become "familiar." That is, although pilot research revealed no further notable decrease in reaction time or number of errors between days 3 and 4 or days 4 or 5 for novel stimuli, these criteria may not

have been sufficient for development of a "routinized" code within the left cerebral hemisphere (Goldberg & Costa, 1981). Subjects have had many years of experience with digit stimuli, and three days experience with the angle stimuli may not have allowed these stimuli to become "familiar" as defined in this model.

A third explanation for no laterality differences obtained for processing novel stimuli may be related to a greater variability in cognitive strategies for novel stimuli in comparison to familiar stimuli. All subjects were questioned concerning the strategies they used to perform these tasks. However, as no systematic debriefing procedure was utilized, these data were not included in the results section and are only suggestive of the cognitive strategies subjects relied upon. It is possible that a lack of consistency in strategies reported for novel stimuli resulted in confounding variance in the results.

With respect to familiar stimuli, most subjects reported that they memorized the digits either in the order they appeared in the memory set, or that they rearranged them and memorized them in numerical order. Most subjects indicated that they rehearsed the memory set throughout each trial block. In contrast, no consistent strategies were reported with angle stimuli. Some subjects reported that they associated the stimuli with "hands on a clock" and thus attempted to memorize memory set items by the time of day

that the angles represented. Other subjects associated angle stimuli with mathematical quadrants. Others utilized verbal names such as "big angle" versus "little angle" in combination with directional orientation of the angles (i.e., up, down, to the side).

In addition to this inter-subject variability in strategies utilized for angle stimuli, some subjects reported that they changed strategies between memory sets and/or between days. If subjects switched strategies more frequently for angle stimuli, it is possible that new information was provided on these trials. It has been suggested that when new information appears on each trial, laterality effects are either miniscule or are not obtained (Hardyck, Tzeng, & Wang, 1978), which may be related to the observation of no visual field advantage for angle stimuli in this experiment.

The inconclusive findings obtained with respect to the serial-parallel dichotomy and laterality differences indicate that there is a need for further refinement of these processing strategies in accordance with Townsend's (1972, 1976) mathematical definitions. There are also indications that additional variables need to be evaluated and controlled for. For example, there are indications that serial and parallel processing are related to verbal encodability of the stimuli. Cohen (1973) suggested that verbally-mediated matching is necessarily serial and

parallel matching is confined to matching on the basis of physical characteristics. Although Cohen did obtain evidence for a serial memory scan within the left cerebral hemisphere, differences in memory scanning were also associated with the type of stimuli used. That is, there were indications that nonverbal stimuli were processed in parallel by both cerebral hemispheres and serial processing within the left hemisphere was limited to stimuli which were verbally mediated.

With respect to Shatz's (1979) series of experiments, it is interesting to note that, although the findings suggested serial processing within the left cerebral hemisphere and parallel processing within the right cerebral hemisphere using three types of stimuli, the weakest support for this model was obtained with verbal stimuli (i.e., words). With these stimuli, there were indications of a serial and a parallel memory scanning strategy within each cerebral hemisphere, although the overall strategy was considered to be consistent with a left hemisphere-serial and right hemisphere-parallel model.

There are also indications in the literature that the type of cognitive strategy utilized by subjects may influence memory scanning. For example, in the Niederbuhl and Springer (1979) study, when subjects were instructed to match stimuli as same or different on the basis of physical (visual) analysis, a parallel memory scan was obtained

within both cerebral hemispheres. When instructions stressed verbal rehearsal, a serial memory scan was observed within both cerebral hemispheres. These findings were only obtained in the analysis of distractor items and not in the analysis of target items. The latter appeared to increase in a serial manner as a function of number of targets in the set for left and right visual field presentation.

Several significant effects attributable to polarity of probe (i.e., whether the probe stimulus was positive or negative) were obtained in the present experiment. These findings were not consistent with previous research where either no differences were found (e.g., Madden & Nebes, 1980; Shatz, 1979; Sternberg, 1969, 1975) or polarity of probe was not considered to be of importance in the analysis (e.g., Klatzky & Atkinson, 1971).

In general, reaction time was faster to the positive probe than to the negative probe. The error rate was higher for the positive probe than the negative probe with left visual field presentation, and there was a higher error rate for the positive probe with novel stimuli. These findings suggest the presence of a speed-accuracy trade-off, resulting in faster reaction time for positive probes with a subsequent increase in errors. It would also appear that there was a left hemispheral superiority for positive matches as reflected in a lower error rate. This finding is consistent with previous research as superiority of the

left hemisphere for positive matches has been reported with reaction time data (e.g., Cohen 1973, Madden & Nebes, 1980).

The findings concerning polarity of set also indicated that differential decision criteria were used for familiar and novel stimuli. Regression lines obtained for familiar and novel stimuli as a function of polarity of set and memory set size are presented in Figure 7. For familiar stimuli, the rate of increase in reaction time per unit increase in memory set size was similar for positive and negative probes: the rate of increase for the positive probe was 80% of that for the negative probe. These findings are consistent with that expected for the exhaustive serial memory scan in which the test stimulus is compared successively to all the memorized items, and only after these comparisons are completed is a positive or negative response made (Sternberg, 1969; 1975). Consequently, the rate of increase in reaction time per unit increase in memory set size (provided by the slope of the line) will be equivalent for positive and negative probes.

For novel stimuli, there was a significant difference in the rate of increase in reaction time per unit increase in memory set size for positive and negative probes. The rate of increase for the positive probe was 60% of that for the negative probe. These findings would appear to be consistent with a self-terminating serial scan in which the probe stimulus is compared successively to one item in the

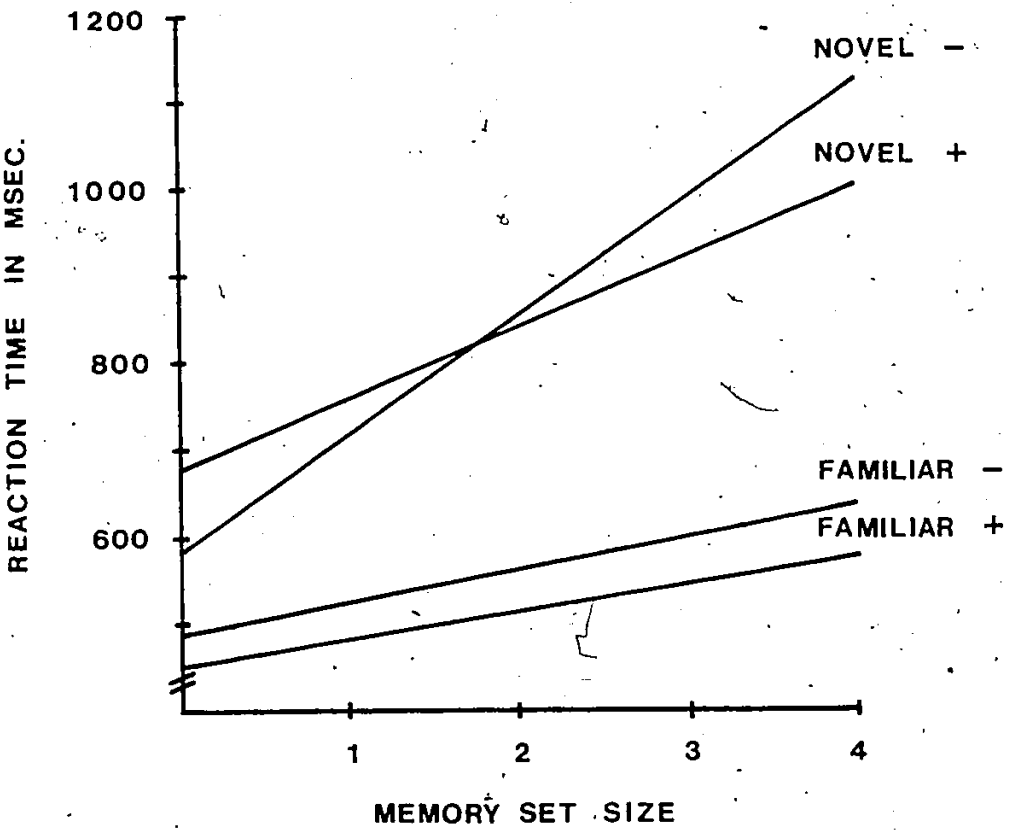


Figure 7. Predicted reaction for familiar and novel stimuli as a function of polarity of probe and memory set size.

memory set after another until either a match occurs, resulting in a positive response, or until all comparisons have been completed, resulting in a negative response. Consequently, the rate of increase for the positive probes will be half of that for the negative probes.

The conclusion of a self-terminating serial search for novel stimuli would be premature since there was a confounding variable. That is, the error rate for positive probes was significantly higher than that for negative probes. Self-terminating and exhaustive scanning cannot be differentiated unless there is a high level of accuracy since it cannot be assumed that all elements have in fact been processed (Townsend, 1972).

The observation of differential decision criteria for familiar and novel stimuli may be related to differences in level of difficulty of these stimuli. For example, for digit stimuli, it is likely that subjects were aware of both the positive and negative sets during each block of trials. That is, due to familiarity with digits, once the positive set was presented, subjects were automatically aware of members of the stimulus ensemble which did not appear (i.e., the negative set). Responses to the probe stimuli were then based upon whether the probe stimulus was positive or negative. The exhaustive serial scan resulted since it is considered to be generally more efficient than a self-terminating serial search (Sternberg, 1969, 1975).

The findings attributable to polarity for novel stimuli may be related to greater difficulty of these stimuli. Subjects may have found it to be advantageous to concentrate only on the positive set during each trial block. That is, owing to less familiarity with these stimuli, when presented with the positive set they were not automatically aware of items in the negative set and continued to focus only on the positive set. Thus, when the probe stimulus was positive, an immediate response was made (i.e., scanning was terminated since there was nothing else left to search). This strategy would result in a "flattening" of the reaction time curve for positive probes. The presence of a speed-accuracy trade-off was also indicated.

Suggestions for Future Research

Comparison of the findings of the present experiment with previous research concerning laterality differences in visual information processing studies affords several suggestions for future research. First, variables which have previously been found to have no significant effects (e.g., polarity of probe), should not necessarily be ignored in these studies. These variables may have significant effects when different methodology and/or stimuli are utilized.

Second, it is apparent that there is a need to further define and evaluate stimulus items which are utilized in

these experiments. That is, stimuli are often selected on the assumption that they are verbal or non-verbal, familiar or novel, and so on. The unknown factor in this research is whether or not subjects perceive these stimuli in the manner in which they were defined. Contradictory findings may occur as a result of subjects' perception of these stimuli differing from that of the researchers.

Third, it is suggested that the type of cognitive strategies utilized by subjects be evaluated and controlled for. Procedures should be developed for systematic questioning of subjects concerning cognitive strategies. There were indications in the present experiment that the strategies utilized by subjects changed over time, resulting in confounding variance. Variability in cognitive strategies within a given subject or between subjects may result in no consistent laterality effects observed for a particular task.

The findings of the present experiment suggest that there is a need for further evaluation of methods used to differentiate serial and parallel processing (e.g., Townsend, 1972, 1976). It would also seem important to investigate the effects of variables such as type of stimuli (e.g., verbal or nonverbal) in association with serial and parallel processing.

Finally, it would also seem important for future research on cerebral asymmetry to account for individual

variability in the laterality effects observed for a particular task. That is, laterality may not be consistent for a particular task but may vary as a function of attention, motivation, cognitive strategies, practice, and other variables (e.g., Goldberg & Costa, 1981; Levy, 1983). The variation in an individual subject's performance over time may have important consequences for models of cerebral asymmetry.

APPENDICES

APPENDIX A

HANDEDNESS QUESTIONNAIRE

NAME: _____

AGE: _____

PROGRAMME (YEAR) : _____

Please answer the following questions by circling "R" for "Right" and "L" for "Left".

R L 1. With which hand do you draw?

R L 2. With which hand do you write?

R L 3. With which hand do you hold a toothbrush?

R L 4. With which hand do you use a hammer?

R L 5. With which hand do you throw a ball to hit a target?

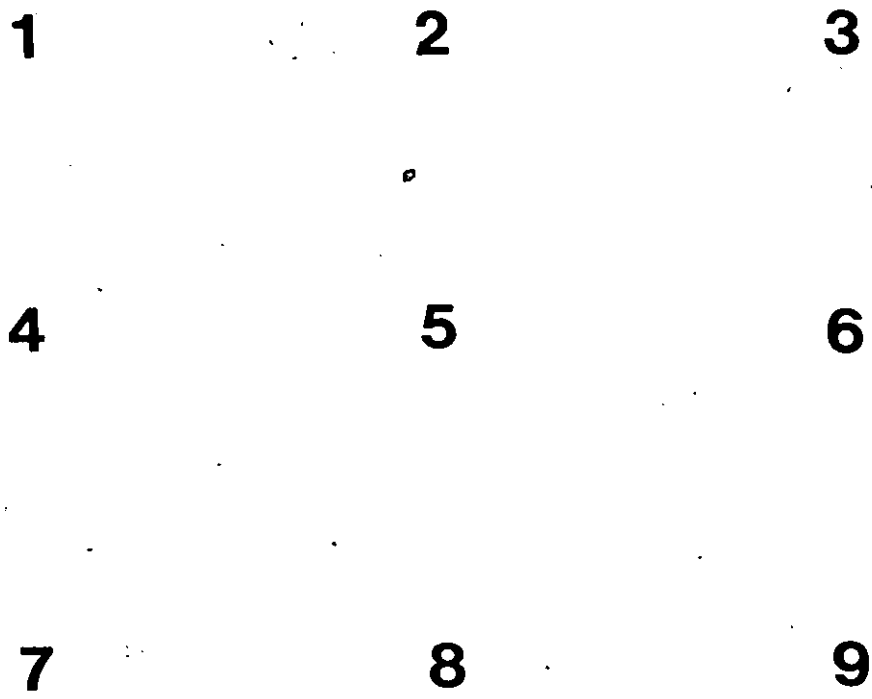
R L 6. With which hand do you use a bottle opener?

R L 7. With which hand do you use an eraser on paper?

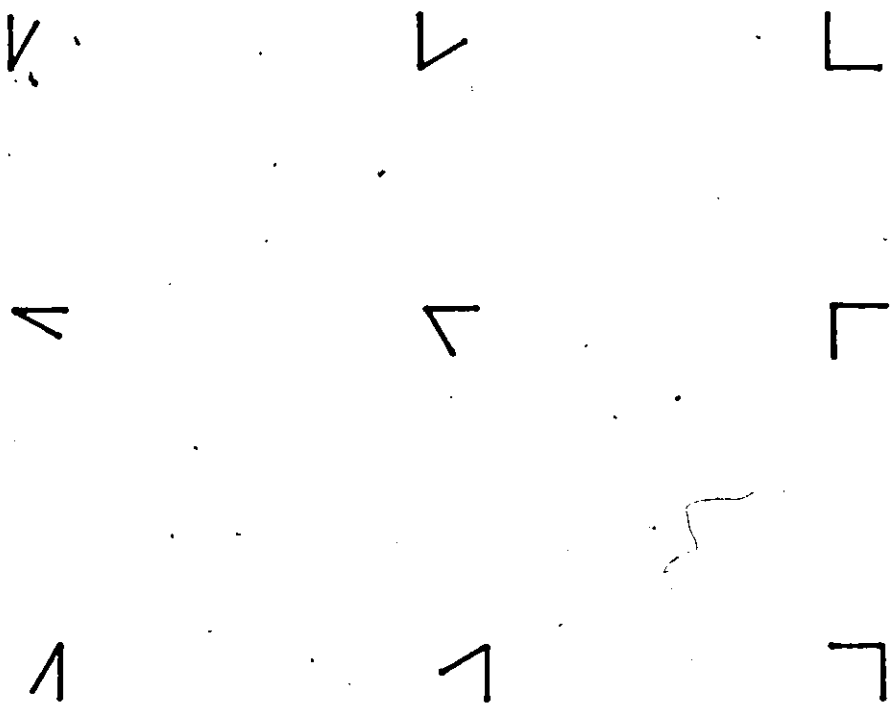
R L 8. With which hand do you remove the top card when dealing?

APPENDIX B

FAMILIAR AND NOVEL STIMULI



FAMILIAR STIMULI



NOVEL STIMULI

APPENDIX C

SUMMARY OF ANOVA ON TRANSFORMED REACTION TIME DATA

ANALYSIS OF VARIANCE PROCEDURE

DEPENDENT VARIABLE: REACR

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE
MODEL	1007	3530.53399927	3.50599205	20.14	0.0001	0.589628
ERROR	14112	2457.19623652	0.17412105		ROOT MSE	
CORRECTED TOTAL	15119	5987.73023579			0.41727814	

C.V.	REACR MEAN
26.5597	1.57109798

SOURCE	DF	ANOVA SS	F VALUE	PR > F
SUB	13	788.70379799	348.43	0.0001
DAY	2	234.55296832	673.53	0.0001
SUB*DAY	26	78.31773882	17.30	0.0001
STIH	1	1771.23406179	10172.43	0.0001
SUB*STIH	13	104.80636453	46.30	0.0001
DAY*STIH	2	5.80786760	16.68	0.0001
SUB*DAY*STIH	26	45.74763433	10.11	0.0001
SIZE	2	155.48253047	446.48	0.0001
SUB*SIZE	26	17.04860207	3.77	0.0001
DAY*SIZE	4	0.98012047	1.41	0.2287
SUB*DAY*SIZE	52	12.19272685	1.35	0.0488
STIH*SIZE	2	0.61805073	1.77	0.1696
SUB*STIH*SIZE	26	18.51517299	4.09	0.0001
DAY*STIH*SIZE	4	0.32688527	0.47	0.7583
SUB*DAY*STIH*SIZE	52	13.14351488	1.45	0.0186
LAT	1	1.16505445	6.69	0.0097
SUB*LAT	13	10.66258864	4.71	0.0001
DAY*LAT	2	0.24146647	0.69	0.4999
SUB*DAY*LAT	26	3.54652792	0.78	0.7737
STIH*LAT	1	0.97035095	5.57	0.0183
SUB*STIH*LAT	13	3.75398230	1.66	0.0625
DAY*STIH*LAT	2	0.24411410	0.70	0.4961
SUB*DAY*STIH*LAT	26	2.38257619	0.53	0.9769
SIZE*LAT	2	2.18199444	6.27	0.0019
SUB*SIZE*LAT	26	4.19432492	0.93	0.5709

DAY*SIZE*LAT	4	1.06291138	1.53	0.1915
SUB*DAY*SIZE*LAT	52	7.08853993	0.78	0.8711
STIH*SIZE*LAT	2	0.43293848	1.24	0.2885
SUB*STIH*SIZE*LAT	26	1.33421268	0.29	0.9998
DAY*STIH*SIZE*LAT	4	0.32068996	0.46	0.7648
SUB*DAY*STIH*SIZ*LAT	52	4.90510488	0.54	0.9971
POL	1	102.13403466	586.57	0.0001
SUB*POL	13	24.51796006	10.83	0.0001
DAY*POL	2	3.54965068	10.19	0.0001
SUB*DAY*POL	26	8.81322359	1.95	0.0027
STIH*POL	1	9.97504170	57.29	0.0001
SUB*STIH*POL	13	9.99482654	4.42	0.0001
DAY*STIH*POL	2	0.73817882	2.12	0.1201
SUB*DAY*STIH*POL	26	4.07542866	0.90	0.6099
SIZE*POL	2	1.86089087	5.34	0.0048
SUB*SIZE*POL	26	8.53315462	1.88	0.0042
DAY*SIZE*POL	4	0.96440899	1.38	0.2364
SUB*DAY*SIZE*POL	52	7.34802299	0.81	0.8319
STIH*SIZE*POL	2	1.46905196	4.22	0.0147
SUB*STIH*SIZE*POL	26	4.12728123	0.91	0.5929
DAY*STIH*SIZE*POL	4	0.40508876	0.58	0.6760
SUB*DAY*STIH*SIZ*POL	52	5.42176665	0.60	0.9902
LAT*POL	1	0.00675841	0.04	0.8438
SUB*LAT*POL	13	6.79603086	3.00	0.0002
DAY*LAT*POL	2	0.06285834	0.18	0.8349
SUB*DAY*LAT*POL	26	2.85573208	0.63	0.9260
STIH*LAT*POL	1	0.35848982	2.06	0.1513
SUB*STIH*LAT*POL	13	7.56019493	3.34	0.0001
DAY*STIH*LAT*POL	2	0.07840464	0.23	0.7984
SUB*DAY*STIH*LAT*POL	26	3.53820260	0.78	0.7760
SIZE*LAT*POL	2	0.36109924	1.04	0.3546
SUB*SIZE*LAT*POL	26	4.47050327	0.99	0.4812
DAY*SIZE*LAT*POL	4	0.37248780	0.53	0.7102
SUB*DAY*SIZE*LAT*POL	52	6.62358597	0.73	0.9260
STIH*SIZE*LAT*POL	2	1.44999320	4.16	0.0156
SUB*STIH*SIZ*LAT*POL	26	2.63508016	0.58	0.9548
DAY*STIH*SIZ*LAT*POL	4	0.98316199	1.41	0.2272
SUB*DAY*STI*SI*LA*PO	52	6.48799098	0.72	0.9383

TESTS OF HYPOTHESES USING THE ANOVA MS FOR SUB*DAY AS AN ERROR TERM

SOURCE	DF	ANOVA SS	F VALUE	PR > F
DAY	2	234.55296832	38.93	0.0001

TESTS OF HYPOTHESES USING THE ANOVA MS FOR SUB*STIM AS AN ERROR TERM

SOURCE	DF	ANOVA SS	F VALUE	PR > F
STIM	1	1771.23406179	219.70	0.0001

TESTS OF HYPOTHESES USING THE ANOVA MS FOR SUB*SIZE AS AN ERROR TERM

SOURCE	DF	ANOVA SS	F VALUE	PR > F
SIZE	2	155.48253047	118.56	0.0001

TESTS OF HYPOTHESES USING THE ANOVA MS FOR SUB*LAT AS AN ERROR TERM

SOURCE	DF	ANOVA SS	F VALUE	PR > F
LAT	1	1.16505445	1.42	0.2546

TESTS OF HYPOTHESES USING THE ANOVA MS FOR SUB*POL AS AN ERROR TERM

SOURCE	DF	ANOVA SS	F VALUE	PR > F
POL	1	102.13403466	54.15	0.0001

TESTS OF HYPOTHESES USING THE ANOVA MS FOR SUB*DAY*STIM AS AN ERROR TERM

SOURCE	DF	ANOVA SS	F VALUE	PR > F
DAY*STIM	2	5.80786760	1.65	0.2115

TESTS OF HYPOTHESES USING THE ANOVA MS FOR SUB*SIZE*LAT AS AN ERROR TERM

SOURCE	DF	ANOVA SS	F VALUE	PR > F
SIZE*LAT	2	2.18199444	6.76	0.0043

TESTS OF HYPOTHESES USING THE ANOVA MS FOR SUB*DAY*POL AS AN ERROR TERM

SOURCE	DF	ANOVA SS	F VALUE	PR > F
DAY*POL	2	3.54965068	5.24	0.0123

TESTS OF HYPOTHESES USING THE ANOVA MS FOR SUB*STIM*POL AS AN ERROR TERM

SOURCE	DF	ANOVA SS	F VALUE	PR > F
STIM*POL	1	9.97504170	12.97	0.0032

TESTS OF HYPOTHESES USING THE ANOVA MS FOR SUB*SIZE*POL AS AN ERROR TERM

SOURCE	DF	ANOVA SS	F VALUE	PR > F
SIZE*POL	2	1.86089087	2.84	0.0770

TESTS OF HYPOTHESES USING THE ANOVA MS FOR SUB*STIM*LAT AS AN ERROR TERM

SOURCE	DF	ANOVA SS	F VALUE	PR > F
STIM*LAT	1	0.97035035	3.36	0.0898

TESTS OF HYPOTHESES USING THE ANOVA MS FOR SUB*STIM*SIZE AS AN ERROR TERM

SOURCE	DF	ANOVA SS	F VALUE	PR > F
STIM*SIZE	2	0.61805073	0.43	0.6526

TESTS OF HYPOTHESES USING THE ANOVA MS FOR SUB*STIM*SIZE*POL AS AN ERROR TERM

SOURCE	DF	ANOVA SS	F VALUE	PR > F
STIM*SIZE*POL	2	1.46905196	4.63	0.0191

TESTS OF HYPOTHESES USING THE ANOVA MS FOR SUB*STIM*SIZE*LAT AS AN ERROR TERM

SOURCE	DF	ANOVA SS	F VALUE	PR > F
STIM*SIZE*LAT	2	0.43293848	4.22	0.0259

APPENDIX D

SUMMARY OF ANOVA ON ERROR DATA

ANALYSIS OF VARIANCE PROCEDURE

DEPENDENT VARIABLE: ERR

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE
MODEL	1007	119.03326720	0.11820583	2.34	0.0001	0.143166
ERROR	14112	712.40000000	0.05048186		ROOT MSE	
CORRECTED TOTAL	15119	831.43326720			0.22468168	

SOURCE	DF	C.V.	ERR MEAN
		384.7324	0.05839947

SOURCE	DF	ANOVA SS	F VALUE	PR > F
SUB	13	13.46567460	20.52	0.0001
DAY	2	5.13703704	50.88	0.0001
SUB*DAY	26	3.38333333	2.58	0.0001
STIM	1	23.10059524	457.60	0.0001
SUB*STIM	13	11.29107143	17.21	0.0001
DAY*STIM	2	3.74444444	37.09	0.0001
SUB*DAY*STIM	26	3.31666667	2.53	0.0001
SIZE	2	3.43544974	34.03	0.0001
SUB*SIZE	26	3.51269841	2.68	0.0001
DAY*SIZE	4	0.45542328	2.26	0.0606
SUB*DAY*SIZE	52	2.80198413	1.07	0.3444
STIM*SIZE	2	1.67777778	16.62	0.0001
SUB*STIM*SIZE	26	2.81111111	2.14	0.0006
DAY*STIM*SIZE	4	0.61468254	3.04	0.0161
SUB*DAY*STIM*SIZE	52	3.00198413	1.14	0.2227
LAT	1	0.52387566	10.38	0.0013
SUB*LAT	13	0.87149471	1.33	0.1871
DAY*LAT	2	0.00687831	0.07	0.9341
SUB*DAY*LAT	26	1.47275132	1.12	0.3035
STIM*LAT	1	0.04821429	0.96	0.3284
SUB*STIM*LAT	13	1.03234127	1.57	0.0843
DAY*STIM*LAT	2	0.23333333	2.31	0.0992
SUB*DAY*STIM*LAT	26	1.46111111	1.11	0.3139
SIZE*LAT	2	0.06402116	0.63	0.5304
SUB*SIZE*LAT	26	0.87671958	0.67	0.8974

DAY*SIZE*LAT	4	0.22843915	1.13	0.3396
SUB*DAY*SIZE*LAT	52	1.61415344	0.61	0.9868
STIH*SIZE*LAT	2	0.10000000	0.99	0.3714
SUB*STIH*SIZE*LAT	26	0.87777778	0.67	0.8968
DAY*STIH*SIZE*LAT	4	0.17976190	0.89	0.4687
SUB*DAY*STIH*SIZ*LAT	52	1.92579365	0.73	0.9241
POL	1	1.13498677	22.48	0.0001
SUB*POL	13	1.76779101	2.69	0.0009
DAY*POL	2	0.15925926	1.58	0.2065
SUB*DAY*POL	26	1.86851852	1.42	0.0748
STIH*POL	1	1.00059524	19.82	0.0001
SUB*STIH*POL	13	1.34292328	2.05	0.0142
DAY*STIH*POL	2	0.16349206	1.62	0.1981
SUB*DAY*STIH*POL	26	1.19021164	0.91	0.6001
SIZE*POL	2	0.10370370	1.03	0.3581
SUB*SIZE*POL	26	1.11851852	0.85	0.6800
DAY*SIZE*POL	4	0.12288360	0.61	0.6565
SUB*DAY*SIZE*POL	52	1.78267196	0.68	0.9628
STIH*SIZE*POL	2	0.12857143	1.27	0.2799
SUB*STIH*SIZE*POL	26	1.24179894	0.95	0.5418
DAY*STIH*SIZE*POL	4	0.14722222	0.73	0.5719
SUB*DAY*STIH*SIZ*POL	52	2.04351852	0.78	0.8766
LAT*POL	1	0.27943122	5.54	0.0187
SUB*LAT*POL	13	0.54927249	0.84	0.6216
DAY*LAT*POL	2	0.05132275	0.51	0.6015
SUB*DAY*LAT*POL	26	1.28386243	0.98	0.4947
STIH*LAT*POL	1	0.07202381	1.43	0.2323
SUB*STIH*LAT*POL	13	0.86408730	1.32	0.1936
DAY*STIH*LAT*POL	2	0.00158730	0.02	0.9844
SUB*DAY*STIH*LAT*POL	26	1.10396825	0.84	0.6958
SIZE*LAT*POL	2	0.05132275	0.51	0.6015
SUB*SIZE*LAT*POL	26	1.02275132	0.78	0.7790
DAY*SIZE*LAT*POL	4	0.09113757	0.45	0.7715
SUB*DAY*SIZE*LAT*POL	52	1.42923280	0.54	0.9969
STIH*SIZE*LAT*POL	2	0.07619048	0.75	0.4702
SUB*STIH*SIZ*LAT*POL	26	1.30158730	0.99	0.4752
DAY*STIH*SIZ*LAT*POL	4	0.49484127	2.45	0.0439
SUB*DAY*STI*SI*LA*PO	52	1.77738095	0.68	0.9638

TESTS OF HYPOTHESES USING THE ANOVA MS FOR SUB*DAY AS AN ERROR TERM

SOURCE	DF	ANOVA SS	F VALUE	PR > F
DAY	2	5.13703704	19.74	0.0001

TESTS OF HYPOTHESES USING THE ANOVA MS FOR SUB*STIM AS AN ERROR TERM

SOURCE	DF	ANOVA SS	F VALUE	PR > F
STIM	1	23.10059524	26.60	0.0002

TESTS OF HYPOTHESES USING THE ANOVA MS FOR SUB*SIZE AS AN ERROR TERM

SOURCE	DF	ANOVA SS	F VALUE	PR > F
SIZE	2	3.43544974	12.71	0.0001

TESTS OF HYPOTHESES USING THE ANOVA MS FOR SUB*LAT AS AN ERROR TERM

SOURCE	DF	ANOVA SS	F VALUE	PR > F
LAT	1	0.52387566	7.81	0.0152

TESTS OF HYPOTHESES USING THE ANOVA MS FOR SUB*POL AS AN ERROR TERM

SOURCE	DF	ANOVA SS	F VALUE	PR > F
POL	1	1.13498677	8.35	0.0127

TESTS OF HYPOTHESES USING THE ANOVA MS FOR SUB*DAY*STIM AS AN ERROR TERM

SOURCE	DF	ANOVA SS	F VALUE	PR > F
DAY*STIM	2	3.74444444	14.68	0.0001

TESTS OF HYPOTHESES USING THE ANOVA MS FOR SUB*SIZE*LAT AS AN ERROR TERM

SOURCE	DF	ANOVA SS	F VALUE	PR > F
SIZE*LAT	2	0.06402116	0.95	0.4000

TESTS OF HYPOTHESES USING THE ANOVA MS FOR SUB*DAY*POL AS AN ERROR TERM

SOURCE	DF	ANOVA SS	F VALUE	PR > F
DAY*POL	2	0.15925926	1.11	0.3453

TESTS OF HYPOTHESES USING THE ANOVA MS FOR SUB*STIM*POL AS AN ERROR TERM

SOURCE	DF	ANOVA SS	F VALUE	PR > F
STIM*POL	1	1.00059524	9.69	0.0082

TESTS OF HYPOTHESES USING THE ANOVA MS FOR SUB*SIZE*POL AS AN ERROR TERM

SOURCE	DF	ANOVA SS	F VALUE	PR > F
SIZE*POL	2	0.10370370	1.21	0.3158

TESTS OF HYPOTHESES USING THE ANOVA MS FOR SUB*STIM*LAT AS AN ERROR TERM

SOURCE	DF	ANOVA SS	F VALUE	PR > F
STIM*LAT	1	0.04821429	0.61	0.4498

TESTS OF HYPOTHESES USING THE ANOVA MS FOR SUB*STIM*SIZE AS AN ERROR TERM

SOURCE	DF	ANOVA SS	F VALUE	PR > F
STIM*SIZE	2	1.67777778	7.76	0.0023

TESTS OF HYPOTHESES USING THE ANOVA MS FOR SUB*LAT*POL AS AN ERROR TERM

SOURCE	DF	ANOVA SS	F VALUE	PR > F
LAT*POL	1	0.27943122	6.61	0.0232

TESTS OF HYPOTHESES USING THE ANOVA MS FOR SUB*DAY*STIM*SIZE AS AN ERROR TERM

SOURCE	DF	ANOVA SS	F VALUE	PR > F
DAY*STIM*SIZE	4	0.61468254	2.66	0.0427

TESTS OF HYPOTHESES USING THE ANOVA MS FOR SUB*STIM*SIZE*LAT AS AN ERROR TERM

SOURCE	DF	ANOVA SS	F VALUE	PR > F
STIM*SIZE*LAT	2	0.10000000	1.48	0.2460

APPENDIX E

SUMMARY OF SIMPLE EFFECTS

Summary of simple simple main effects on transformed reaction time data

Source	SS	df	MS	F
Laterality X Size X Stimulus				
Lat at Size 2, Familiar	3.53	1	3.53	13.78 *
Lat at Size 3, Familiar	0.06	1	0.06	<1
Lat at Size 4, Familiar	0.82	1	0.82	3.19
Lat at Size 2, Novel	0.18	1	0.18	<1
Lat at Size 3, Novel	0.15	1	0.15	<1
Lat at Size 4, Novel	0.01	1	0.01	<1
error	19.95	78	0.26	
Size X Laterality X Stimulus				
Size at LVF, Familiar	31.43	2	15.71	54.37 *
Size at RVF, Familiar	47.46	2	23.73	82.11 *
Size at LVF, Novel	37.52	2	18.76	64.91 *
Size at RVF, Novel	43.31	2	21.16	73.20 *
error	26.33	91	0.29	
Polarity X Size X Stimulus				
Pol at Size 2, Familiar	29.26	1	29.26	48.37 *
Pol at Size 3, Familiar	26.17	1	26.17	43.25 *
Pol at Size 4, Familiar	32.73	1	32.73	54.09 *
Pol at Size 2, Novel	2.05	1	2.05	3.38 *
Pol at Size 3, Novel	10.47	1	10.47	17.30 *
Pol at Size 4, Novel	14.77	1	14.77	24.41 *
error	47.17	78	0.61	
Size X Polarity X Stimulus				
Size at Positive, Familiar	37.07	2	18.54	42.51 *
Size at Negative, Familiar	39.73	2	19.86	45.56 *
Size at Positive, Novel	25.89	2	12.95	29.69 *
Size at Negative, Novel	56.73	2	28.37	65.06 *
error	39.70	91	0.44	

* $p < .001$

Summary of simple main effects on

transformed reaction time data

Source	SS	df	MS	F
Day X Polarity				
Day at Positive	147.88	2	73.94	44.13 **
Day at Negative	90.23	2	45.11	26.93 **
error	87.13	52	1.68	
Polarity X Day				
Polarity at Day 1	19.75	1	19.75	23.11 **
Polarity at Day 2	35.52	1	35.52	41.56 **
Polarity at Day 3	50.41	1	50.41	58.99 **
error	33.33	39	0.85	
Laterality X Size				
Laterality at Size 2	2.65	1	2.65	6.96 *
Laterality at Size 3	0.21	1	0.21	<1
Laterality at Size 4	0.49	1	0.49	1.28
error	14.86	39	0.38	
Size X Laterality				
Size at LVF	68.79	2	34.40	84.20 **
Size at RVF	88.87	2	44.43	108.77 **
error	21.24	52	0.41	
Polarity X Stimulus				
Polarity at Familiar	87.98	1	87.98	66.15 **
Polarity at Novel	24.14	1	24.14	18.15 **
error	34.51	26	1.33	

* $p < .05$
** $p < .001$

Summary of simple simple main effects on error data

Source	SS	df	MS	F
Size X Day X Stimulus				
Size at Day 1, Familiar	0.07	2	0.04	<1
Size at Day 2, Familiar	0.05	2	0.02	<1
Size at Day 3, Familiar	0.12	2	0.06	<1
Size at Day 1, Novel	3.63	2	1.82	23.29 *
Size at Day 2, Novel	1.96	2	0.98	12.55 *
Size at Day 3, Novel	0.35	2	0.17	2.22
error	12.13	156	0.08	
Day X Stimulus X Size				
Day at Size 2, Familiar	0.06	2	0.03	<1
Day at Size 3, Familiar	0.07	2	0.04	<1
Day at Size 4, Familiar	0.03	2	0.02	<1
Day at Size 2, Novel	1.49	2	0.75	9.65 *
Day at Size 3, Novel	2.22	2	1.11	14.39 *
Day at Size 4, Novel	6.10	2	3.05	39.58 *
error	12.00	156	0.08	

* $p < .001$

Summary of simple main effects on error data

Source	SS	df	MS	F
Day X Stimulus				
Day at Familiar	0.06	2	0.03	<1
Day at Novel	8.82	2	4.41	34.23 **
error	6.70	52	0.13	
Stimulus X Day				
Stimulus at Day 1	17.50	1	17.50	46.67 **
Stimulus at Day 2	7.24	1	7.24	19.30 **
Stimulus at Day 3	2.11	1	2.11	5.62 *
error	14.61	39	0.38	
Size X Stimulus				
Size at Familiar	0.16	2	0.08	<1
Size at Novel	4.96	2	2.48	20.39 **
error	6.32	52	0.12	
Polarity X Stimulus				
Polarity at Familiar	0.01	1	0.02	<1
Polarity at Novel	2.13	1	2.13	17.83 **
error	3.11	26	0.12	
Laterality X Polarity				
Laterality at Positive	0.78	1	0.78	14.36 **
Laterality at Negative	0.02	1	0.02	<1
error	1.42	26	0.06	
Polarity X Laterality				
Polarity at LVF	1.27	1	1.27	14.26 **
Polarity at RVF	0.14	1	0.14	<1.62
error	2.32	26	0.09	

* $p < .05$
** $p < .001$

APPENDIX F

SUMMARY TABLES OF RAW REACTION TIME DATA

Mean raw reaction time for familiar and novel stimuli as a function of day, laterality, and day X laterality

	Stimulus			
	Familiar		Novel	
Variable	Mean	(S.D.)	Mean	(S.D.)
Day				
Day 1	627.76	(222.12)	1120.75	(512.69)
Day 2	559.47	(184.21)	926.49	(393.65)
Day 3	536.20	(172.90)	820.04	(335.83)
Laterality				
Left Visual Field	578.86	(199.99)	953.25	(431.82)
Right Visual Field	570.09	(197.02)	958.27	(445.20)
Day X Laterality				
Left Visual Field				
Day 1	632.69	(224.13)	1106.52	(494.68)
Day 2	563.59	(189.54)	926.81	(394.29)
Day 3	540.30	(167.57)	826.43	(345.29)
Right Visual Field				
Day 1	622.83	(220.07)	1134.98	(529.89)
Day 2	555.35	(178.71)	926.17	(393.17)
Day 3	532.10	(178.05)	813.64	(326.12)

Mean raw reaction time for familiar and novel stimuli as a function of laterality X set size

	Stimulus			
	Familiar		Novel	
Variable	Mean	(S.D.)	Mean	(S.D.)
Laterality X Set Size				
Left Visual Field				
Size = 2	547.65	(199.72)	848.02	(351.81)
Size = 3	575.39	(182.03)	939.81	(393.69)
Size = 4	613.55	(208.92)	1071.93	(505.56)
Right Visual Field				
Size = 2	526.40	(179.35)	852.05	(382.99)
Size = 3	584.26	(204.89)	963.29	(444.04)
Size = 4	599.61	(198.45)	1059.46	(479.08)

Mean raw reaction time for polarity of probe as a function of day, stimulus, and stimulus X memory set size

	Polarity of Probe			
	Positive		Negative	
Variable	Mean	(S.D.)	Mean	(S.D.)
Day				
Day 1	843.31	(447.16)	905.20	(481.55)
Day 2	711.98	(350.05)	773.98	(363.07)
Day 3	645.32	(299.49)	710.92	(301.88)
Stimulus				
Familiar	545.99	(194.10)	602.97	(197.88)
Novel	921.09	(424.55)	990.43	(449.49)
Stimulus X Set Size				
Familiar				
Size = 2	510.25	(186.61)	563.80	(189.80)
Size = 3	555.25	(196.31)	604.41	(188.17)
Size = 4	572.47	(194.05)	640.69	(207.70)
Novel				
Size = 2	843.56	(365.19)	856.50	(370.15)
Size = 3	913.66	(411.92)	989.43	(424.13)
Size = 4	1006.03	(473.99)	1125.36	(503.38)

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